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CONTENTS

	Page	Russian Page
GEOGRAPHIC-SOIL REGIONALIZATION OF THE USSR, by Ye. N. Ivanova, et al.	1084	1
PHYSICOCHEMICAL AND COLLOIDOCHEMICAL PROCESSES OCCURRING IN SOILS BASED ON LATEST RESEARCH, by Di Gleriya Yanosh	1093	12
THE NATURE OF ORGANO-MINERAL COLLOIDS AND METHODS OF THEIR STUDY, by L. N. Aleksandrova and M. Nad'	1100	21
SYNTHETIC SOIL CONDITIONERS, by P. V. Vershinin	1106	28
EFFECT OF SOIL LIMING ON PHOSPHORUS ASSIMILATION BY PLANTS, by D. M. Alekseyeva	1114	38
DYNAMICS OF SOIL MOISTURE IN RELATION TO TOPOGRAPHY, by S. N. Taychinov and M. M. Fayzullin	1121	46
DISCUSSION		
THE STATUS AND DEVELOPMENT OF CLASSIFICATION PROBLEMS IN SOIL SCIENCE, by Ye. N. Ivanova and N. N. Rozov	1127	54
METHODS		
ACIDITY CHANGES IN SANDY SOILS AS AFFECTED BY THE HILL METHOD OF APPLYING FERTILIZERS, by M. S. Zhukov	1135	64
COLOR CHANGES OF NORTHERN SURFACE SOILS, by P. G. Aderikhin and Ye. P. Tikhova	1142	70
DYNAMICS OF NITRATES AND MOISTURE IN ORDINARY CHERNOZEMS OF DIFFERENT LAND USES IN THE KUYBYSHEV OBLAST', by O. N. Koroleva	1148	76

Page Russian Page

EFFECT OF THE MAJOR BIOLOGICAL FACTORS ON AIR COMPOSITION OF ALLUVIAL SOILS IN THE KLYAZ'MA RIVER FLOOD PLAIN, by M. T. Yastrebov 1155 81

REVIEWS

CHEMISTRY OF THE SOIL, Edited by Firman E. Bear 1163 89

VALUABLE RESEARCH ON TROPICAL SOILS -- THE SOILS OF EAST CENTRAL JAVA, by T. V. J. Dames 1166 92

CHRONICLE

BASIC RESULTS OF THE WORK AND FUTURE TASKS OF THE KUYBYSHEV DIVISION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS, by D. I. Burov. 1168 94

THE WORK OF THE DAGESTAN DIVISION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS, by A. S. Soldatov 1170 95

SECOND REPUBLIC CONFERENCE OF KAZAKHSTAN SOIL SCIENTISTS, by Sh. A. Chulakov 1171 95

WORK OF THE SESSION ON PROBLEMS OF SOIL SCIENCE OF THE SECTION ON AGRICULTURE, UKRAINIAN ACADEMY OF AGRICULTURAL SCIENCES, by A. M. Grinchenko 1173 97

OBITUARY

ALEKSEY GRIGOR'YEVICH DOYARENKO, by a group of students and collaborators 1175 99

BIBLIOGRAPHY 1176 100

This issue of Pochvovedeniye introduces a new format designed to shorten the procedures involved in translation and publication of the journal.

The time lapse between Russian publication and English translation will now be narrowed -- a matter of importance to all Soil Scientists.

GEOGRAPHIC-SOIL REGIONALIZATION OF THE USSR

YE. N. IVANOVA, P. A. LETUNOV, N. N. ROZOV,
V. M. FRIDLAND and S. A. SHUVALOV[1]
V. V. Dokuchayev Soil Institute
and Council for the Study of Productive Resources,
Academy of Sciences, USSR

The resolutions of the Twentieth Congress of the Communist Party of the Soviet Union dealt with the problem of a rational distribution and specialization of agricultural production, evaluating local soil-climatic and economic conditions so that maximum yield of agricultural products per 100 hectares of arable land with minimum expenditures of labor and resources might be obtained. This task required systematization of our knowledge of the natural features of agricultural areas of the USSR and their evaluation from the viewpoint of potentialities for production of various products.

The last two years in the scientific institutions of the V.I. Lenin All-Union Academy of Agricultural Sciences (VASKhNIL) and in the local agricultural institutions of all republics, oblasts and krays, have been devoted to the development of zonal systems. These systems are to be the basis on which the economy will be developed and technical and organizational measures put into motion to increase agricultural production per 100 hectares of arable land. The work is being carried out with due consideration for differences in natural features in individual zones and regions. All oblasts, krays and republics have completed the regionalization of natural features, the basis on which soil regionalization will be developed everywhere.

Early in 1954 work was resumed on the regionalization of natural features, especially on geographic-soils regionalization, under the direction of the Academy of Sciences, USSR, and instructions by the State Planning Committee of the Council of Ministers of the USSR. A group of soil scientists, geographers and botanists of the V. V. Dokuchayev Soil Institute, the Institute of Geography, the Botanical Institute and the Council for the Study of Productive Resources (SOPS) under the direction of Academicians, I. P. Gerasimov and I. V. Tyurin, drew up a plan for the division of the USSR into natural zones and provinces. This regionalization plan was reported by N. N. Rozov and P. A. Letunov to the All-Union Conference of Soil Scientists in 1954 and again at the beginning of 1956. It is based on materials related to the natural-historical regionalization of the USSR conceived by the Academy of Sciences, USSR, in 1939-1943 and on subsequent data from studies on geographic soil conditions of individual regions of the USSR. The basic requirement for the 1954 plan of regionalization was that bioclimatic criteria were to be used for the largest classes in the regionalization -- the delineation of natural zones and provinces -- and not the geomorphological criteria which had been the basis for delineation of natural provinces in the 1947 regionalization.

The natural-economic regionalization of the USSR was completed at the same time. Thirty-six groups of administrative oblasts were delineated, combined into natural-economic regions on the basis of similarity of natural features and basic orientation of agricultural production, and their boundaries were drawn to agree with the boundaries of the administrative oblasts. On this framework of natural-economic regions the economics staff of the Department of Agricultural Resources of the SOPS, under the direction of Academician, V. S. Nemchinov, attempted to develop a long-range plan for agricultural production and re-allocation of objectives oriented toward assuring the needs of the people according to scientifically based norms and guaranteeing other needs of the State for agricultural products. The results of this work have been recently published.

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[1] Report to the First Delegates Congress, All-Union Society of Soil Scientists. The following persons, in addition to the authors of the report, assisted in compilation of the regionalization map and descriptions of the delineated areas: N. I. Bazilevich, K. P. Bogatyrev, O. A. Vadkovskaya, Iv. P. Gerasimov, A. A. Yerokhina, N. A. Nogina, V. A. Nosin, A. M. Petelina, Ye. N. Rudneva and K. A. Ufimtseva. The bioclimatic basis for the attached regionalization plan came from data provided by D. I. Shashko.

Parallel to this, work is continuing in the USSR Academy of Sciences to refine and effect a still more detailed breakdown of the plan of natural and geographic-soil regionalization. Beginning in 1956 at the invitation of the Academy of Sciences, USSR, several State universities participated in a regionalization study under direct control of the Methodological Bureau organized at the Moscow State University. Representatives of the USSR Academy of Sciences participated in the study. The universities are working on a detailed regionalization of individual regions comprising almost all the territory of the Union. Work is continuing in the USSR Academy of Sciences on the overall regionalization of the entire USSR, and the possibility of developing a unified system of regionalization with the adjoining countries of The People's Democracy is being studied.

The practical importance of the work on detailed regionalization of natural features became additionally significant following resolutions of the February Plenary Session of the Central Committee of the Communist Party of the Soviet Union (TsK KPSS) and of the April Session of the Supreme Soviet of the USSR. They related to continued strengthening of the kolkhoz structure and reorganization of the machine tractor stations (MTS). It assumed additional significance after the decrees of the July Plenary Session of the TsK KPSS relative to abolition of obligatory deliveries and payments in kind for the work of the machine tractor stations and the new system, prices and conditions of purchase for agricultural products. The need arose for establishment of a Soviet economic cadastral survey to plan and organize properly the agricultural economy and to plan purchases. To accomplish this work it was necessary not only to compile large-scale soil maps of State and Collective farms, but also to develop an All-Union site quality, and economic scales related to soils and soil regions in the detailed regionalization plan. This work has been started by the SOPS, the V. V. Dokuchayev Soil Institute and the All-Union Institute of Agricultural Economics of the VASKhNIL. In all republics and oblasts of the Soviet Union the work of regionalization is recognized as having great practical and national-economic importance; in many of the Union republics it is being accomplished as a direct governmental task. The results of the regionalization work are being presented under various names: soils or agricultural soils, natural (natural-historical) or natural-economic. Essentially, however, in all cases the task is to divide the territory into more or less homogeneous parts (regions) according to the association of soils with climate, relief and other elements of the natural environment as factors in soil formation and as conditions directly influencing agricultural production.

This approach to regionalization for agricultural purposes should be recognized unquestionably as the proper one. However, there are shortcomings in its implementation. One common defect is the variety of systems of taxonomic regionalization units; that is, different interpretation and use of such subdivisions as regions (oblasts), provinces (provintsiya), districts (okrug), subdistricts (rayon) and others.

Some authors use only units of geomorphological regionalization for taxonomic subdivisions higher than soil subdistricts (rayon), especially in regionalization of mountainous territories. It is impossible not to notice that some authors have given varying descriptions and meanings to soil subdistricts (rayon). However, despite varying characteristics for the taxonomic units of regionalization used for different areas, one notes an effort in devising these systems to reconcile and organically connect two relatively independent lines of division of the territory: 1) in accordance with the bioclimatic factors, and 2) in accordance with lithological-geomorphological features.

Thus, the methodological task is to find correct ways and means to reconcile and correlate these two lines at all stages of regionalization. This problem may be solved by taking the principles used in drawing up the system of taxonomic units for compilation of the plan for general regionalization of the USSR.

In analyzing the system of taxonomic units to be used for geographic soils regionalization of the USSR, it is most necessary to consider the interrelationship between soil-graphical regionalization and soil cartography.

Soil-geographical regionalization is the method of delineation of territories uniformly into: 1) the structure of the soil cover, 2) the combination of soil forming factors, and 3) the type of possible agricultural utilization.

The basis of soil-geographical regionalization is the genetic soil cartography. Soil mapping uses the cartographic method to show the areal distribution of soil classification -- group, sub-group, genus and species in pure form or in combinations. The task of soil-geographical regionalization involves the delimitation of areas in which there are homogeneous structures of the soil cover; that is, soil combinations of various mapping units.

Work on soil-geographical regionalization amounts to classifying soil units and drawing boundaries of these classification categories. The taxonomic system of soil-geographical regionalization is arranged by analyzing the structure, nature and genesis of soil units, and at the same time considering the geographical factors which determine the structure of soil units.

The fundamental taxonomic units are: 1) the soil zone (on plains), and 2) the vertical soil zones or mountain soil province (in mountainous areas). Thus, the taxonomic system of soil-geographical regionalization can be enlarged.

We understand the soil zone to include the areal distribution of a zonal soil group and the intrazonal soils included in it. In the regionalization plan worked out for USSR agricultural purposes, often two soil groups or subgroups have been combined. For example, the light chestnut and brown soils have been combined into one semi-desert zone; podzolized, leached and typical chernozems have been combined into the forest-steppe zone. This is due to the inadequate study of agronomic differences of certain adjoining soil groups as well as several incomplete soil classifications.

A vertical soil zone or mountain soil province is an areal distribution of interrelated vertical soil zones.

We can regard the latitudinal and vertical soil zones as a macro-unit of soil. In this, one may lineate units of lower orders to provide a basis for formulating the descending branch of the taxonomic system of soil-geographical regionalization. The ascending branch of the taxonomic system is derived by combining soil zones and mountain soil provinces into soil-bioclimatic regions and soil-bioclimatic belts.

The necessity to combine soil zones and mountain provinces into soil-bioclimatic regions and belts became clear when we had to determine a unified system of regionalization for the USSR and neighboring people's democracies, especially the Chinese People's Republic. Without delimiting the higher categories of regionalization it was difficult to establish a unifed regionalization plan.

The taxonomic system as a whole has the following form: 1) Soils-bioclimatic belt, 2) Soils-bioclimatic region, 3) Soil zone, vertical soil zone (or mountain province), 4) Soil province, vertical belt, 5) Soil area, mountain soil area, 6) Soil district, mountain soil district.

The basic taxonomic units of soil-geographical regionalization are given in the legend of the map (Fig. 1). In addition, the following can be delimited: on plains -- subzones and groups of soil provinces (phases); in mountainous areas -- groups of soil provinces, vertical soil zones and subzones.

The soil-bioclimatic belt is that association of soil zones and vertical soil zones (mountain soil provinces) combined because of similar radiational and thermal conditions and their similar influence on soil formation, weathering and development of vegetation.

The soil-bioclimatic region is the association of soil zones and vertical soil zones included in a climatic belt not only because of similar radiational and thermal conditions, but also because of moisture and continentality conditions and their influence on soil formation, weathering and development of vegetation.

Thus, the determining conditions for delimitation of soil bioclimatic belts are predominantly thermal; those for delimitation of regions are chiefly moisture and continentality. These conditions, however, are neither considered independently, nor measured in the usual units. They are regarded in relation to their influence on soil formation, weathering and development of vegetation. This effect is expressed by agricultural climatic (bioclimatic) indices.

In climatology and geography it has long been the custom to distinguish the following four climatic and natural belts: 1) cold (polar), 2) temperate (boreal), 3) warm (subtropical), and 4) hot (tropical).

This simple classification for soils and agronomy requires further breakdown. Considering the actual distribution of soils zones and agricultural crops, we should supplement them by dividing the temperate and warm belts into sub-belts: cold-temperate, temperate, warm-temperate and warm (Table 1).

In our scheme, sub-belts of the temperate and warm belts are regarded as belts whose limits are characterized by unequal total temperatures. In western Eurasia they are higher; in eastern Eurasia, lower. Evidently this is due to special thermal conditions during the summer season in a region of monsoon climate.

The various belts of the earth receive unequal amounts of precipitation, as may be seen from the average latitudinal norms of precipitation (for the entire world, including the oceans) as worked out by A. I. Kaygorodov. If these computations are taken only for land areas and refer to the average annual temperature of the belt, then it becomes quite clear how sharply the soil-bioclimatic belts differ with respect to moisture. I. P. Gerasimov

Table 1

Climatic data for soil bioclimatic belts and sub-belts

Soil-bioclimatic		Total temperatures on southern boundaries of belts, above 10°		Average latitudinal norms of total precipitation (After A. I. Kaygorodov)
Belt	Sub-belt	Western Eurasia	Eastern Eurasia	
Cold		700	600	200-300
Temperate	Cold-temperate	2400	1800	400-800
	Temperate	4000	3200	900
Warm	Warm-temperate	6000	5000	800
	Warm	8000	7000	800
Hot				900-1800

noted this and delimited xerothermal and hydrothermal belts.

The differences in moisture are reflected in the spatial relationships of areas of humid and arid regions. The xerothermal subtropical belts include immense arid regions in the centers of continents, and the humid regions in these belts occupy only narrow strips along the seashores.

Within the USSR there are four soil-bioclimatic belts: 1) cold (polar), 2) cold-temperate (boreal), 3) temperate (subboreal), and 4) warm-temperate (subtropical).

In Figure 1, the following soil-bioclimatic regions have been delineated:

In the cold (polar) belt.

A. The Eurasian Polar Region with arctic and tundra soils.

The cold-temperate (boreal) belt clearly consists of four regions: two oceanic and two continental.

B. The Western Meadow-Forest Region of sod, acidic nonpodzolized and unusually brown podzolized forest soils. This encompasses the northern part of Western Europe and is represented within the USSR by only one province, Kaliningrad.

C. The Central Taiga-Forest Region belt extends across the European plain and Western Siberia, almost to the Yenisey. It is characterized by a drier and more severe climate with an increase in continentality from west to east. It is subdivided into soil zones and subzones: gleyey-podzolic, podzolic, sod-podzolic and grey forest soils.

D. The Eastern Siberian Permafrost-Taiga Region includes Eastern Siberia, a region of permanent and prolonged seasonal freezing. It is characterized by gleyey frozen taiga, light yellow frozen taiga, sod-podzolic, permanently frozen, and grey forest permanently frozen soils.

E. The Far Eastern Meadow-Forest Region influenced by the Pacific Ocean is characterized by sod, acidic, nonpodzolized and unusual sod-podzolic soils.

In the temperate (subboreal) belt there are five regions: two humid-oceanic, one transitional, and two arid-continental.

F. The Western Brown Soil-Forest Region extends across the plains and mountain provinces of Western Europe. In the USSR it occupies the mountain soil provinces of the Carpathians, the Crimea, and Northern and Eastern Caucasus. These areas are characterized by brown soil formation.

G. The Central Forest Steppe and Steppe Region encompasses broad expanses of the steppes in European and Asiatic USSR extending into China and Mongolia. It is characterized by a diminution of marine influences, an increase in temperature in southern zones and an increase in continentality in eastern zones. It includes the forest-steppe zone of podzolized, leached and typical chernozems, the steppe zone of ordinary and southern chernozems, and the dry steppe zone of dark-chestnut and chestnut soils.

H. The Eastern Brown-Soil-Forest Region with its occurrence of brown forest soils is influenced by the Pacific Ocean monsoons giving rise to relatively extensive areas.

I. The Desert-Steppe and Desert Region is in the central part of the Eurasian continent where maximum aridity and the most intense continentality occur. It includes a semi-desert zone of light-chestnut and brown soils, a desert zone of gray-brown soils and a foothill-semi-desert zone of peculiar low-carbonate sierozems.

J. The High Mountain Desert Region of the Pamirs and the Tyan-Shan extends eastward to the mountainous regions of China.

The same scheme of oceanic influences occurs in the warm-temperate (subtropical) belt.

K. The Warm-Temperate Humid Forest Region within USSR boundaries occurs in the western part of the belt and it occupies relatively small sectors in the Western and Eastern Transcaucasus. It is characterized by krasnozems and zheltozems.

L. The Warm-Temperate Xerophtic-Forest and Shrub-Steppe Region extends northward into USSR territory from Asia Minor, occurring in relatively small areas. It is characterized by cinnamon-colored and gray-cinnamon soils.

M. The Subtropical Warm-Temperate Semi-Desert and Desert Region occurs on the Eastern Transcaucasus plains and the southern part of Central Asia extending east into China. It is characterized by gray-brown soils of the southern type and sierozems. Farther east, within the boundaries of the Chinese People's Republic, there is another moist subtropical region caused by the Pacific Ocean monsoons.

The delineation of belts and regions is of great theoretical and practical significance. We note, from the standpoint of a world soil classification, that a soils-bioclimatic belt includes soils of one world group, and a soils-bioclimatic region includes soils of one class.

The practical significance of the delineation of regions can be briefly illustrated by an example from the Eastern Siberian permafrost taiga region. In its southern agricultural part the phenomenon of prolonged seasonal freezing caused by extreme continentality is widespread. Research on the soil moisture-heat regime has been performed by the Amur Expedition of the Academy of Sciences, USSR, by N.D. Pustovoytov and others under the direction of N.A. Kachinskiy and V.A. Kovd; in Buryat-Mongolia and in Chita Oblast', by N.A. Nogina and others under the direction of A.A. Rode; in Krasnoyarskiy Krag, by Yu. P. Veredchenko and A.A. Yerokhina. These scientists demonstrated that sod-podzolic, grey forest soils and leached chernozems freeze to a depth of 2 or 3 meters, with complete thawing between July and August. The long-lasting frozen layer causes increased soil moisture directly above the frozen layer, often in the form of ponded water. This supplementary moisture results in a more stable water supply for crops in the critical development period, larger summer harvests and fewer annual variations. The seasonal freezing changes the conditions of soil solution mobility. Low soil temperatures no doubt retard soil-biological processes in the first part of the growing season. Combined with a constant moisture supply, this should insure a high degree of effectiveness of mineral fertilizers, especially those of the nitrogen types. Thus, soil cultivation problems are unique. These phenomena are widespread throughout the permafrost taiga region and clearly distinguish it from western regions -- the Central Taiga-Forest and Central Forest-Steppe and Steppe Regions. Specially adapted agricultural methods must be devised for development of such an area.

In exactly the same way a series of substantial variations between the dry springs and pronounced soil saturation in the second half of the summer characterize the monsoon climate of the Far Eastern regions. As we have seen, each soil-bioclimatic region has its own system of soil zones.

A soil zone is an areal occurrence of a zonal soil and its associated intrazonal soils. Soil zones may have not only a latitudinal but also a meridional extension (Eastern China, North America, Eastern Australia). Therefore, we can distinguish latitudinal and meridional sections of soil zones.

A soil province is a part of a soil zone, distinguished by specific soil characteristics and conditions of soil formation, associated either with differences in moisture and continentality (in the latitudinal sections of the soil zones), or with temperature differences (in the meridional sections of the soil zones). The development of provincial differences within the boundaries of soil zones is of great significance to agronomy.

A mountain soil province (or vertical soil zone) is an areal occurrence of interconnected vertical soil zones determined by the position of the mountainous area (or a part of it) in the system of soils-bioclimatic regions and the major features of its general orography. Among these orographic features, according to the soil scientists of the Chinese People's Republic (who have done the most work on this problem), we can distinguish mountainous, plateau, mountain-basin and mountain-plain soil provinces having specific characteristics within the structure of vertical soil zones.

Inasmuch as the structure of vertical zones in the mountains is primarily determined by the position of the mountainous area in the system of climatic belts and regions, the taxonomic position of a mountain soil province within the system of regionalization is analogous to a soil zone in the plains area.

A vertical soil belt is a part of the vertical soil zone and is characterized by the predominance of a given zonal mountain soil group in conjunction with other zonal and intrazonal soil groups.

The soil bioclimatic provinces are delineated in Figure 1. A total of 67 provinces are represented in plains areas and 35 mountain soil provinces in mountainous areas.

A soil area is a part of a soil province or vertical soil zone and is characterized by a given genetic type of relief (or an orderly combination of several genetic types of relief), specifically determined from associations of soil-forming rocks and soils. A district is also distinguished by peculiarities of the local climate and vegetation cover.

The Meshcher Lowlands with sandy loam and sandy sod-podzolic soils in association with sod-gley and peat-bog soils are examples of districts, regions having a terminal moraine landscape with a complex combination of soils, morainic plains with sod-podzolic soils, etc.

The area, in turn, is subdivided into more uniform units or soil districts. By the term soil district we mean that part of a soil district having a uniform combination of relief forms and a uniform soil cover. The soils-geographical district is the primary unit of natural-economic regionalization.

The proposed system of taxonomic units is a further development and refinement of the system proposed in 1956. For units smaller than a soil zone this same system was suggested by the Committee on Methodology in Soils Regionalization of Moscow State University following our report in the spring of 1956 and its subsequent improvements in the spring of 1957.

At the present time the delineation of areas and districts is being conducted primarily on a local basis by regionalization of individual republics, oblasts and krays. Our collective has just now begun to work out an All-Union map of soil districts. In the future the Academy of Sciences, USSR, plans to produce a map showing the divisions of areas in USSR territory and the soil districts for selected territories. This work is necessary in order to provide a basis for detailed agricultural regionalization and for geographical correlation of the results of this work with site quality index and the economic evaluation of land. In those areas where there are branches of the Society of Soil Scientists, it will be necessary to work out and collectively debate proposed maps of soil-geographical regionalization. The maps will be broken down to the district level and, where necessary, even to smaller units. It is very important that there be correlation between the regionalization of adjoining administrative oblasts.

The overall geographical, genetic and agronomic-soils description of the delineated districts, areas, provinces and other units of regionalization is a very serious task. It is important that together with a profound study of soil processes and their relationships to local combinations of factors involved in soil formation, a sufficiently detailed study be made of the agronomic and soil reclamation characteristics of the territory. For this we would need additional data on the agrobiological characteristics of the climate, the water and thermal regimes of the soils, their physical and technical properties, nutrient supply, data on the seasonal dynamics of available nutrients and other characteristics of the soil important to production. When describing soil districts it is necessary to include the problem of arable lands, the possibilities for and the conditions under which cultivated areas may be expanded and the measures which must be taken for reclamation and soil protection.

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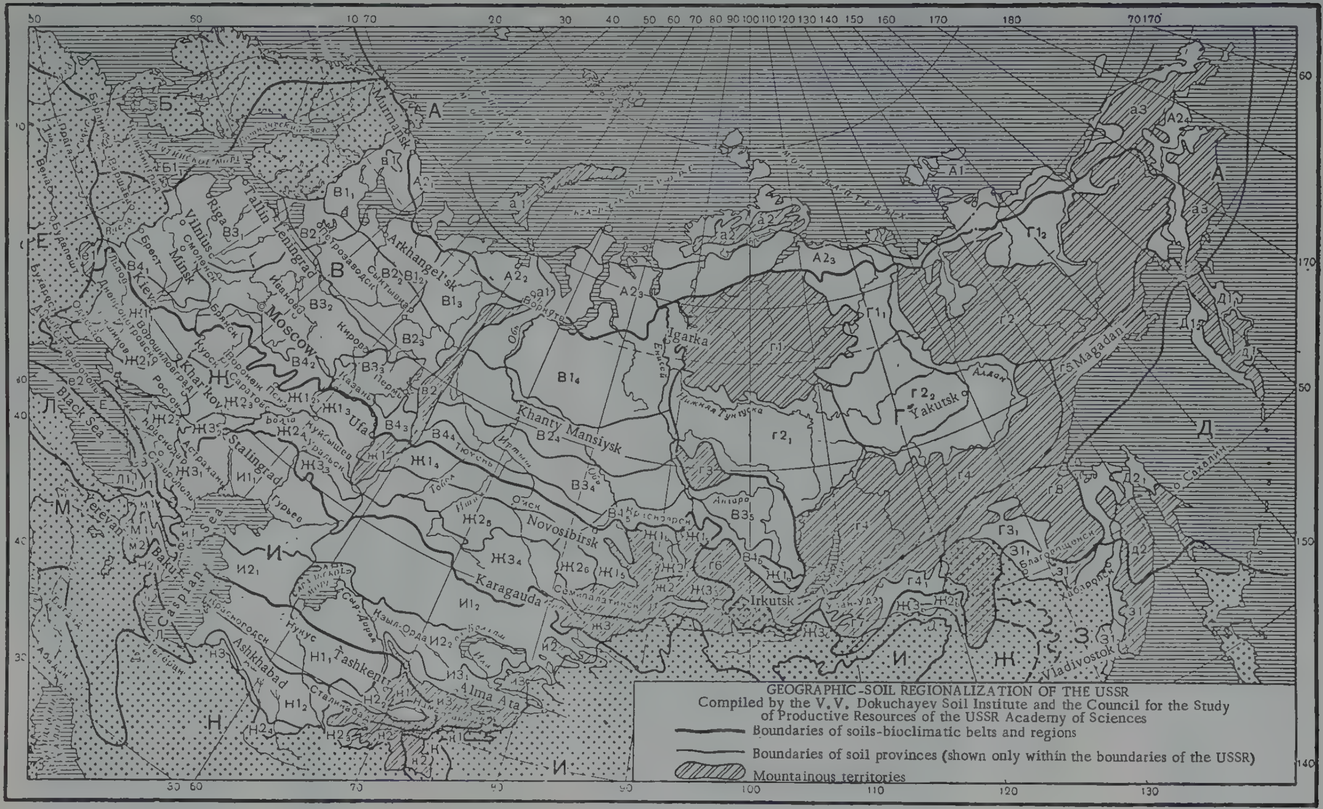

GEOGRAPHIC-SOIL REGIONALIZATION OF THE USSR
Compiled by the V. V. Dokuchayev Soil Institute and the Council for the Study of Productive Resources of the USSR Academy of Sciences

Note: Transliteration is limited to selected place names.

LEGEND TO DIAGRAMMATIC MAP

"Geographic-Soil Regionalization of the USSR (1958)"

POLAR (COLD) BELT

A. Eurasian Polar Region

A1. Arctic zone; A2. Subarctic zone of tundra soils. Provinces: A2$_1$. Kola; A2$_2$. Kanin-Pechora; A2$_3$. Northern Siberia; A2$_4$. Chukota-Anadyr. Mountain Provinces: a1. Ural-Novaya Zemlya; a2. Taymyr; a3. Chukota.

BOREAL (COLD-TEMPERATE) BELT

Б. Western Meadow-Forest Region

Б$_1$. Kaliningrad province

B. Central Taiga-Forest Region

B1. Northern taiga sub-zone of gleyed-podzolic soils. Provinces: B1$_1$. Kola-Karelia; B1$_2$. Onega-Mezen; B1$_3$. Pechora; B1$_4$. Western Siberia; B2. Central taiga sub-zone of podzolic soils. Provinces: B2$_1$. Karelia; B2$_2$. Dvina; B2$_3$. Vychegda-Pechora; B2$_4$. Western Siberia; B3. Southern taiga sub-zone of sod-podzolic soils. Provinces: B3$_1$. Baltic area-Belorussia; B3$_2$. Central Russia; B3$_3$. Vyatka-Kama; B3$_4$. Western Siberia; B3$_5$. Angara area; B4. Deciduous forest zone of grey forest soils. Provinces: B4$_1$. Ukraine; B4$_2$. Central Russia; B4$_3$. Kama area; B4$_4$. Western Siberia; B4$_5$. Central Siberia. Mountain Provinces: B1. Khibiniy; B2. Ural.

Г. Eastern Siberian Permafrost-Taiga Region

Г1. Northern taiga sub-zone of gleyey-permafrost-taiga soils. Provinces: Г 1$_1$. Northern Lena; Г1$_2$. Yana-Kolyma; Г 2. Central taiga sub-zone of permafrost-taiga and pale-yellow soils. Provinces; Г 2$_1$. Central Siberia; Г 2$_2$. Central Yakutia; Г 3. Southern taiga sub-zone of sod-podzolic permafrost soils; Г 3$_1$. Upper Zeya province; Г 4. Deciduous forest zone of grey, forest permafrost soils; Г 4$_1$. Transbaykal province. Mountain Provinces: 1. Putoran; г 2. Verhoyansk-Kolyma; г 3. Yenisey area; г 4. Baykal-Aldan; г 5. Okhotsk; г 6. Eastern Sayans; г 7. Southern Transbaykal; г 8. Upper Amur-Bureya.

D. Far Eastern Meadow-Forest Region

D. Meadow-forest zone of sod soils. Provinces: D1$_1$. Eastern Kamchatka; D1$_2$. Western Kamchatka; D2. Taiga-deciduous-forest zone of acid non-podzolized and sod-podzolic soils; D2$_1$. Amur-Northern Sakhalin province. Mountain Provinces: D1. Kamchatka; D2. Sikhota-Alin-Sakhalin.

SUB-BOREAL (TEMPERATE) BELT

E. Western Brown Earth-Forest Region

Mountain Provinces: e1. Carpathians; e2. Crimean; e3. Northern Caucasus; e4. Eastern Caucasus.

Ж. Central Forest Steppe and Steppe Region

Ж1. Forest steppe zone of podzolized, leached and typical chernozems and grey forest soils. Provinces: Ж1$_1$. Ukraine; Ж 1$_2$. Northern Russia; Ж 1$_3$. Trans-Volga; Ж 1$_4$. Western Siberia; Ж1$_5$. Cis-Altai; Ж 1$_6$. Central Siberia; Ж 2. Steppe zone of ordinary and southern chernozems. Provinces: Ж 2$_1$. Ukraine; Ж 2$_2$. Azov area Cis-Caucasus; Ж 2$_3$. Central Russia; Ж 2$_4$. Trans-Volga; Ж 2$_5$. Kazakhstan; Ж 2$_6$. Cis-Altai; Ж 2$_7$. Minusinsk; Ж 2$_8$. Chita; Ж 3. Dry steppe zone of dark chestnut and chestnut soils. Provinces: Ж 3$_1$. Eastern Cis-Caucasus; Ж 3$_2$. Don; Ж 3$_3$. Trans-Volga; Ж 3$_4$. Kazakhstan; Ж 3$_5$. Tuva-Mongolia; Ж 3$_6$. Chita. Mountain Provinces: ж 1. Southern Urals; ж 2. Altai-Sayan; ж 3. Southern Altai.

З. Eastern Brown Earth-Forest Region

З1. Broadleaf-forest zone of brown forest soils. Provinces: З1$_1$. Zeya-Bureya; З 1$_2$. Ussuri-Khanka. Mountain Provinces: з 1. Southern Sikhota-Alin.

И . Desert-Steppe and Desert Region

И1. Semi-desert zone of light chestnut and brown soils. Provinces: И 1_1. Caspian area; И 1_2. Kazakhstan; И 2. Desert zone of grey-brown soils. Provinces: И 2_1. Aral-Caspian; И 2_2. Aral-Balkash; И 3. Foothills-semi-desert zone of low carbonate sierozems; И 3_1. Northern Tyan-Shan area province. Mountain Provinces: и 1. Inner Degestan; и 2. Saur-Tarbagatay; и 3. Northern Tyan-Shan.

K. High-Mountain Desert Region

Mountain Provinces: K1. Central Tyan-Shan; K2. Pamirs.

SUB-TROPICAL (WARM TEMPERATE) BELT

Л Sub-Tropical Warm-Temperate Humid-Forest Region

Л1. Zone of Humid forests with Zheltozem and kraznozem soils. Provinces: Л 1. Kolkhid (Colchis). Mountain Provinces: л 1. Western Caucasus; л 2. Lenkoran.

M. Sub-Tropical, Warm-Temperate, Zerophytic Forest and Brush Steppe Region

M1. Zone of cinnamon-colored and grey-cinnamon soils. Provinces: $M1_1$. Alazan-Kura. Mountain Provinces: M1. Eastern Transcaucasus; M2. Southern Transcaucasus.

H. Sub-Tropical Warm-Temperate Semi-Desert and Desert Region

H1. Desert zone of "grey-brown" soils. Provinces: $H1_1$. Northern Turan; $H1_2$. Southern Turan; H2. Foothills-semi-desert zone of sierozems. Provinces: $H2_1$. Kura-Araks; $H2_2$. Western Tyan-Shan area; $H2_3$. Southern Tadzhikistan; $H2_4$. Kopet-Dagh area. Mountain Provinces: H1. Alay-Western Tyan-Shan; H2. Badakhshan-Hissar; H3. Kopet-Dagh.

PHYSICOCHEMICAL AND COLLOIDOCHEMICAL PROCESSES OCCURRING IN SOILS BASED ON LATEST RESEARCH[1]

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Contemporary development of physical and colloidal chemistry allows more utilization of the processes occurring in soil and aids in the advancement of more accurate concepts. In particular, one may conclude that the majority of chemical transformations in soil are associated with the loss or gain of two elementary particles — the proton and the electron.

In the mineral portion of the soil the most important role is played by protolytic processes characterized by proton loss and gain. Other transformations occurring in the mineral part of the soil and in the humus are oxidation-reduction processes associated with electron loss or gain. The transition of electrons is catalyzed by enzymes, the products of the activity of living organisms in the soil. The principal inorganic elements of the soil participating in these oxidation-reduction reactions are iron and manganese acting as the electron transmitter (donor) or electron collector (acceptor).

A proton or hydrogen ion has a radius of 10^{-13} cm; i.e., five orders of magnitude smaller than the average radius of molecules and ions. This determines its special behavior. A proton stays very briefly in a free state because it possesses a great capacity for combining with electrons. According to research by Fajans, the concentration of protons in water is 10^{-150} moles per liter. This means that there are practically no free protons in water. In the presence of water molecules all free protons immediately penetrate their electron envelopes and the water molecule is transformed into an ion of H_3O^+ (hydroxons). The proton remains a very short time (approximately 10^{-12} seconds) in the same molecule since, influenced by the attraction of the electron envelopes of neighboring molecules, it constantly enters new water molecules. Thus, one may consider a proton or H_3O^+ to have properties identical to those of other ions.

PROTOLYTIC REACTIONS OCCURRING IN WATER SOLUTIONS

The proton's capacity for combining with water molecules is so great that in the presence of water it leaves the molecules of strong acids and forms H_3O^+ ions. This characteristic of the proton, as well as the dissociation of acids in different solvents, led Bronsted to present a new interpretation of the nature of acids and bases derived from the reactions between the proton and the solvent. According to Bronsted's theory, all those substances (molecules, ions) capable of liberating protons are called acids. Substances which take protons, however, are called bases. For example, ions of HCO_3^- in relation to ions of OH^- behave as acids since they transmit protons. At the same time they receive protons from acetic acid, thus acting as bases. According to Bronsted's concept, both neutral molecules and ions can be acids and bases. Water molecules act as bases in relation to acids and, in reverse reactions, they act as acids. For example, HCl in the presence of water transmits one proton to the water thus converting the water to an H_3O^+, as shown in the following equation:

$$HCl+H_2O \rightleftarrows Cl^-+H_3O^+ \qquad (1)$$

Ammonia (NH_3) takes away one proton from the water molecule and is transformed into an ammonium ion as shown in the following equation:

$$NH_3+H_2O \rightleftarrows NH_4^++OH^- \qquad (2)$$

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[1] Report presented to the First All-Union Delegates' Congress of Soil Scientists in Moscow, May 1958.

In this reaction water acts as an acid since t loses a proton and is transformed into a ydroxyl ion. The process, characterized by quation (1) where there is a strong acid such s hydrochloric acid moves in the direction of he upper arrow. A different picture is observed when there are weak acids such as cetic acid, since the acetate ion bonds proons with greater force than the anions of strong cids. In such cases protons are distributed etween the acetic acid and H_3O^+ ions, dependng on the acetic acid concentration. The comlete protolization of acetic acid occurs only vhen dilutions are infinitely large.

The pH values of buffer solutions can change ignificantly when concentrated solutions of trong electrolytes are added. If we add calium chloride in various concentrations to a uffer solution of acetic acid and acetate, then he pH value of the solution will change as hown in Table 1. With increasing quantities f calcium chloride, there is a corresponding ncrease in the C_H value of the solution and, onsequently, a corresponding decrease in its H. This phenomenon is explained in the ollowing way: between the acetic acid and the cetate ions, just as between the water moleules and H_3O^+, there is a dynamic equilibrim; that is, in a unit time the molecules of cetic acid transfer as many protons to the ater molecules as are transferred by the $_3O^+$ to the acetate ions. This equilibrium hanges in the presence of other ions only if ley are in large concentration. The change associated with the structure of solutions strong electrolytes. The distribution of ns is uniform only when there is large diluon. In the more concentrated solutions, the stribution of ions resembles the crystal ttice of salts; that is, the anions are surounded by a layer of cations, and the cations, a layer of anions. Similarly, the distribuon in the buffer solution of acetate-acetic cid with or without an extraneous electrolyte, expressed by equations (3) and (4). If the olution contains Ca and Cl ions in addition to ater, the CH_3COO^- at the moment of their rmation from acetic acid are surrounded by layer of calcium ions, but a layer of chlorine ns is formed around the H_3O^+. The layer of ions makes the transfer of protons from e CH_3COO^- difficult, and the layer of chlore ions is an obstacle to the breaking away of otons from the H_3O^+. As a result, the action moves in the direction of the upper arrow. More concentrated solutions of salts form thicker layers of ions; therefore, the higher the concentration of the solution, the greater the migration.

Table 1

Effect of calcium chloride concentrations on the pH values of buffer solution of acetate-acetic acids in 1:1 preparations

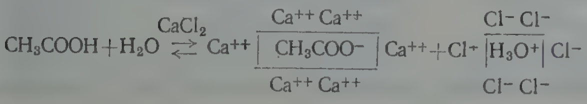
Concentrations of N calcium chloride	pH solution	C_Hx10[illegible] solution
0.0	4.60	0.25
0.1	4.46	0.35
0.2	4.37	0.43
0.3	4.29	0.51
0.4	4.24	0.58
0.5	4.18	0.66
5.5	3.25	5.62

The protolytic processes are important for soil science, because they also take place in soil solutions. This applies especially to concentrated solutions of salts, whose influence must be considered during the drying processes of soils.

PROTOLYTIC REACTIONS OCCURRING ON INTERFACES OF SOLID PARTICLES

Protolytic reactions may occur not only in solutions, but also in liquid and solid interfaces. A loss or gain of protons may occur between the liquid and solid phases until equilibrium is reached. Such reactions are observed when precipitates are formed. It is well known that during the formation of barium sulfate the pH value of the filtrate differs depending on the presence of barium chloride or barium sulfate. If solutions of barium chloride and potassium sulfate are mixed in equal quantities, ions of barium and sulfate will be present in a 1:1 ratio on the surfaces of the forming particles. The electro-kinetic potential of the particles (micelles) of barium sulfate formed under these conditions is

$$CH_3COOH + H_2O \rightleftarrows CH_3COO^- + H_3O^+ \tag{3}$$



$$CH_3COOH + H_2O \overset{CaCl_2}{\rightleftarrows} Ca^{++} \underset{Ca^{++}\,Ca^{++}}{\overset{Ca^{++}\,Ca^{++}}{\boxed{CH_3COO^-}}} Ca^{++} + Cl^- \underset{Cl^-\,Cl^-}{\overset{Cl^-\,Cl^-}{\boxed{H_3O^+}}} Cl^- \tag{4}$$

approximately zero and the pH of the liquid phase is almost neutral. A different picture is observed if barium chloride is present in excessive quantity when barium sulfate is precipitated. In such cases the electro-kinetic potential of the particles of barium sulfate will be positive and the pH of the liquid moves toward acidification.

Table 2

Effect of barium ion concentrations on the electro-kinetic potential (micelles) of barium sulfate and on the pH value of the liquid phase

Concentrations of barium ions in the filtrate, meq/l	Electro-kinetic potential of micelles, mv	pH liquid phase
0	+ 5.6	6.0
14.6	+25.0	5.3
29.8	+33.0	5.2
59.6	+39.5	5.1
119.2	+48.5	4.8

Data in Table 2 show the effect of barium chloride in excessive quantity on the electro-kinetic potential of the micelles of barium sulfate, and also the pH value of the liquid phase. It is obvious that with an increase in the concentration of barium ions the electro-kinetic potential of barium sulfate becomes positive and the pH value of the liquid phase drops. This phenomenon is due to the fact that the excessive barium ions occupy areas on the surfaces of the barium sulfate particles. The positive charge of these ions only partially neutralizes the crystal lattice; therefore, the excess of charges outwardly gives a positive charge to the particle. Part of these positive charges bond the water molecules. Influenced by closely adjoining positive charges, these molecules cannot, like free water molecules, hold their protons; therefore, part of the protons are transferred to the latter, transform- them into H_3O^+. A resulting increase in the concentration of these ions in the liquid phase occurs causing a drop in the pH value. Under the influence of an excess of potassium sulfate the electro-kinetic potential of the particles of barium sulfate formed during precipitation becomes negative, while the pH of the liquid phase moves toward alkalization. This phenomenon is clearly shown in the data in Table 3. It is explained as follows: when there is an excess of sulfate ions in the medium, they attach themselves to the barium sulfate particles being formed. The negative charges of the sulfate ions are only partially neutralized by the crystal lattice; hence, the micelle charge becomes negative. The bonding of the oxygen of the water protons leads to the liberation of hydroxyl ions and the pH increases.

The protolytic reactions occurring on the interfaces play an important role in soils. The phenomena and laws discussed previously can thus be used to explain a number of processes occurring in the soil.

Table 3

Effect of sulfate ion concentrations in the electro-kinetic potential of micelles of barium sulfate and on the pH value in the liquid phase

Concentration of sulfate ions in the filtrate, meq/l	Electro-kinetic potential of micelles, mv	pH liquid phase
0	+ 5.6	6.0
14.6	-28.0	6.2
29.8	-36.0	6.3
59.6	-42.0	6.4
119.2	-47.0	6.5

PROTOLYTIC ADSORPTION PROCESSES OCCURRING ON SURFACES OF SOIL PARTICLES

The processes taking place on the surface of soil particles or in the solvate layer surrounding them depend considerably on the structure of this surface. The ions and radicals found there are bonded on the one hand to the crystal lattice of the soil particles by the forces of this lattice, and on the other hand, are in contact with the solvate layer surrounding the soil particles. This solvate layer, caused by an electrical charge of ions on the outer part of the solid phase, is completely unneutralized. The processes occurring in the soil can be represented on a model of a soil particle which shows the active areas -- the radicals which participate in the reaction.

In Figure 1 the vertical lines separate the solid part of the soil particle, the solvate layer and the soil solution. On the surface of the soil particles the minus sign (-) designates areas of negative charges, and the plus (+) denotes positive charges. The H symbol indicates proton loss and the OH symbol represents radicals free to give off OH ions. The K symbol in the solvate layer corresponds to

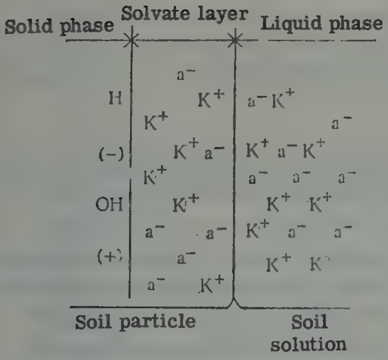


Fig. 1. Structures of the surfaces of soil particles and the solvate layers.

adsorbed cations on the surface of the soil particles and the "a⁻" symbol designates adsorbed anions. Water molecules are not shown in the diagram. From this model soil particles can be pictured as large amphoteric molecules whose surfaces are capable of giving off protons and hydroxyl ions, or more accurately, whose surfaces have areas with positive and negative charges. The radicals designated by the symbol H become positively charged areas after the loss of ions. The negative areas are transformed into radicals with the symbol H after the addition of protons, and the positive areas become radicals containing OH after the addition of OH ions. The exchange of cations and anions on the surface of the particle is shown in Figures 2 and 3.

Ion exchange is a reversible process leading to dynamic equilibrium which occurs when the quantity and type of ions passing between the solvate layer and the soil solution is identical. Protolytic reactions can occur between the surfaces of the soil particles and in the liquid phase. If protons contact the negatively charged areas of a soil particle, the number of its negative charges and its electro-kinetic potential decreases. With a decrease in the number of negatively charged areas part of the adsorbed cations are transferred from the solvate layer to the liquid phase. After receiving protons there is a decrease in the adsorption capacity of the soil cations and, vice-versa; when protons are lost the adsorption capacity of the cations increases. The adsorption capacity of soils with respect to anions is determined by the positively charged areas which numerically decrease if OH ions are bonded on the positively charged areas; they increase when OH radicals pass over into the soil solution from the surfaces of the soil particles. The positively charged areas on the surfaces of the soil particles and the number of OH radicals are in a state of equilibrium with the soil solution and any change occurring in the latter effects their number and ratio. It follows that neither the cation adsorption capacity nor the anion absorption capacity of the soil can be regarded as a constant value since they always depend on the conditions and methods of determination. Numerous investigations have shown that during determination of the absorption capacity of anions

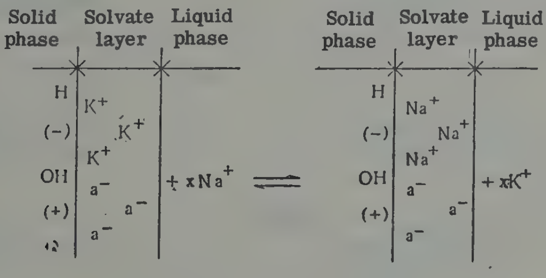


Fig. 2. Exchange of cations on the surfaces of soil particles.

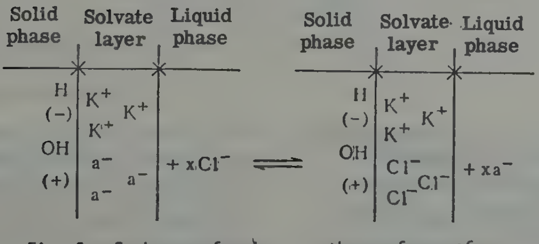


Fig. 3. Exchange of anions on the surfaces of soil particles.

and cations, the pH of the solution used for the exchange has a strong effect on the results received. They do not reflect the situation which exists in reality and can be used only for comparison with each other. This applies especially to the so-called value (T-S) corresponding to the H radicals. The surface of soil particles, solvate layers and liquid phase combined constitute a buffer system whose equilibrium can be changed by salt solutions. If this equilibrium shifts toward acidification when influenced by a salt solution, we refer to it as the action of acid suspension. If, however, it shifts toward alkalization, we refer to it as the action of alkali suspension. The action of acid and alkali suspensions of soils is shown in Figure 4. The graph clearly shows that the action of the acid suspension increases the capacity for cation absorption and decreases the capacity for anion absorption. The action of the alkali suspension was the reverse; that is, it increases the anion absorption capacity.

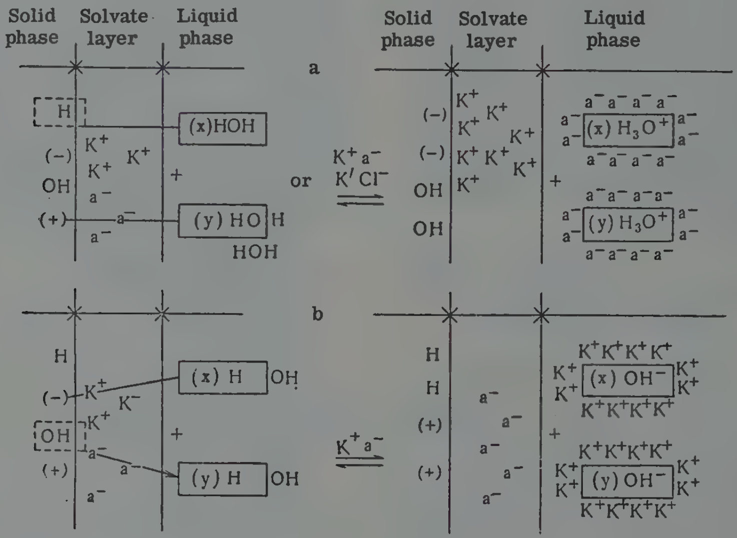


Fig. 4. Effect of the concentration of electrolytes in soil solutions on the protolytic equilibrium between surfaces of soil particles and water.

a -- acidic suspension effect; b -- basic suspension effect

The action of acid suspension of soils particles is frequently encountered. The effect of alkali suspension in soils can be observed only in rare cases. The action of acid suspension explains exchange of acidity in soils; under the influence of a concentrated solution of potassium chloride H_3O^+ is formed which subsequently transforms iron and aluminum oxides into ions of aluminum and iron. It is possible that H_3O^+ can also free iron and aluminum from the crystal lattice of the soil particle.

The capacity for bonding as well as for losing protons is characteristic of different soils. Bonding capacity is determined simply as follows: buffer solutions with different pH values are added to the soil and after interaction occurs the direction in which the pH value of the buffer solution has shifted is determined. From this, either interpolation or the graphic method are used to determine the pH of the buffer solution when the soil is in a state of equilibrium; that is, the steady pH value of the solution after it is added to the soil (the isoelectric value of pH). The soil's capacity to gain and lose protons is characterized by the percentage of acetate ions and acetic acid of the buffer solution and acetate-acetic acid which is in a state of equilibrium with the soil. Tables 4, 5 and 6 give data for several soil profiles illustrating their capacity to gain and lose protons. It should be noted that all experiments were conducted in the presence of potassium chloride. The structure of the solvate layer of soil particles is conveniently

Table 4

Capacity to receive and transmit protons
in light-gray podzolic forest soils (Khekhida)

Buffer systems: acetate-soils	Depths, cm					
	0-18	18-30	30-60	60-90	90-130	130-160
pH in equilibrium	5.2	5.2	3.8	4.1	4.9	5.45
Relationship of acetate ions to acetic acids, computed for pH in equilibrium	6.14	6.4	0.25	0.49	3.7	11.50
Percentage of distribution of acetate ions and acetic acid; acetate ions	86	86	20	33	76	92
Ions of acetic acid	14	14	80	67	24	8

Table 5

Capacity to receive and transmit protons
in crusted-columnar carbonate solonetz (Kartsag)

Buffer systems: acetate-soils	Depths, cm					
	0.5	5-30	32-60	60-80	86-110	110-150
pH in equilibrium	4.7	6.0	6.5	6.72	6.98	7.00
Relationship of acetate ions to acetic acids, computed for pH in equilibrium	1.94	39	124	199	332	400
Percentage of distribution of acetate ions and acetic acid; acetate ions	66	97.5	99.2	99.5	99.7	99.75
Ions of acetic acid	34	2.5	0.8	0.5	0.3	0.25

Table 6

Capacity to bond and transmit protons
in carbonate chernozem (Iregsemche)

Buffer systems: acetate-soils	Depths, cm						
	0-10	10-17	17-28	28-55	55-84	84-110	110-170
pH in equilibrium	6.7	6.75	6.90	6.95	6.98	6.97	7.05
Relationship of acetate ions to acetic acids, computed for pH in equilibrium	200	200	332	332	378	378	444
Percentage of distribution of acetate ions and acetic acid; acetate ions	99.5	99.5	99.7	99.7	99.74	99.74	99.8
Ions of acetic acid	0.5	0.5	0.3	0.3	0.26	0.26	0.2

characterized by determination of the ion concentration in the solvate water. Computations show that the cation concentration in the solvate layer may reach 2-6 meq/1. For protons (H_3O^+) this value reaches 0.5-5 meq/1. Computation of the pH values of the solvate coating shows that their change is insignificant. Thus, it is incorrect to speak of adsorbed H_3O^+.

PROTOLYTIC PROCESSES ASSOCIATED WITH DISINTEGRATED SOIL PARTICLES

Under the action of large concentrations of H_3O^+ or hydroxyl ions, the bonding of soil particles in the crystal lattice is broken and ions of aluminum, iron, magnesium, etc., are released. The H_3O^+ form in large quantities during the biological decomposition of organic soil substances and also in secretions from plant roots. They originate in the mineral part of the soil to a lesser degree. Hydroxyl ions form from the bicarbonate ions of soil solutions during their concentration. According to the equation:

$$2HCO_3^- \rightleftarrows CO_3^{--} + H_2O + CO_2 \qquad (5)$$

carbonates are formed which protolyze the water in accordance with the following reaction:

$$CO_3^{--} + H_2O \rightleftarrows HCO_3^- + OH^- \qquad (6)$$

In other words, OH^- are obtained. This process is observed in salinized soils. In the early spring it is usually possible to discover only bicarbonate ions in the ground water, while in the summer, when the soils dry out, carbonate ions appear in great quantity. Aluminum, iron and magnesium, carried into solution by H_3O^+, migrate downward and are set free in the lower layers; at this time the surface layer of the soil is enriched with silicic acid, since the lattice of the polysilicic acid remains unbroken. Hydroxyl ions accumulated in soils from the silicic acid lattice are capable of freeing silicate and polysilicate ions which under certain conditions may migrate downward into the soil. In these cases aluminum and iron oxides remain in the upper layers of the soil. In our opinion, the study of protolytic processes occurring in the soils is of great significance to research on clay minerals and their formation process.

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THE NATURE OF ORGANO-MINERAL COLLOIDS AND METHODS OF THEIR STUDY

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Notwithstanding the recent achievements in oil and clay mineralogy and the progress in e studies of humus as a system of high olecular organic substances (5, 6), our nowledge of organo-mineral colloids is quite mited. The basic question which to date has ot been resolved concerns the nature of bonds f the two basic components, i.e., mineral olloids and humic substances. Tyulin (10), sing the well-known structural formula of e. N. Gapon, identified two different groups f organo-mineral colloids. In the first roup, humic acid is bonded to the crystal ttice of clay minerals by exchangeable cal-ium, and in the second group, by aluminum. his investigations of the structure of aggre-ates of various soils Antipov-Karatayev ecognized the possibility of such bonds. The eory behind these concepts is based on the rmation of organo-mineral colloids proper hich are chemically bonded between the ystal lattice and humic acid through main lencies. Despite general recognition of ch structure systems, the formation of such mpounds has not been proved.

Beutelspacher (11), studying the reaction tween dialyzed ammonium humates and ay minerals with the electron microscope lieves that neither adsorption of humic acid clay minerals nor orientation of its par-cles occurs unless clay minerals have been tivated by iron.

Noting modern ideas on mineral colloid mposition, we investigated the nature of mic acid reactions with exchangeable tions, non-silicate forms of sesquioxides, d crystal lattice of clay minerals.

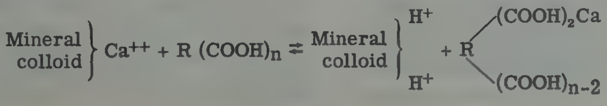
I. The reaction of humic acids or their luble humates with exchangeable cations is ways an exchange reaction resulting in the rmation of a corresponding humate not nded to the mineral's crystal lattice:

This deduction by Aleksandrova (2) was confirmed by studying the dynamics of the reaction process between humic acid and exchangeable cations.

Weighed samples of askanite and chernozem, fully saturated with Ca, Na, Al or H, and containing equal quantities of some cation, were placed in cellophane bags and immersed in the humic acid sol (pH 3.85). This sol was obtained from Na humate in the process of filtration through the SBS resin cationite (ionic) column in H-form. During the experiment, the pH value of the sol was measured and the time of residue formation was recorded.

The exchange nature of the reaction is very well expressed (Fig. 1). In the system of humic acid plus Ca and Na-askanite or chernozem, the pH value of the sol sharply increases; when the concentration of Ca displaced into the solution reaches a certain value the humic acid precipitates. In the system of humic acid plus Al-askanite or chernozem, the pH value changes slightly, and the residue appears a month later, evidently as a result of complex formation. A study of the properties of the Ca humate formed in the process shows that it is easily peptized with a weak alkali solution (0.01 N) without preliminary tréatment with acid or neutral sodium salts. In the process of dehydration its mobility becomes sharply lowered.

This research has made it necessary to correct Gapon's structural formula and to question the possibility of the formation of organo-mineral colloids proper through exchangeable cations, including exchangeable calcium. The positive role of exchangeable calcium is its formation of water insoluble humates which thus prevent the migration of humic acids along the profile and fix them at



$$\left.\begin{matrix}\text{Mineral}\\\text{colloid}\end{matrix}\right\}\mathrm{Ca}^{++} + \mathrm{R\,(COOH)}_n \rightleftharpoons \left.\begin{matrix}\text{Mineral}\\\text{colloid}\end{matrix}\right\}\begin{matrix}\mathrm{H}^+\\ \\ \mathrm{H}^+\end{matrix} + \mathrm{R}\begin{matrix}\diagup\mathrm{(COOH)_2Ca}\\ \\ \diagdown\mathrm{(COOH)}_{n-2}\end{matrix}$$

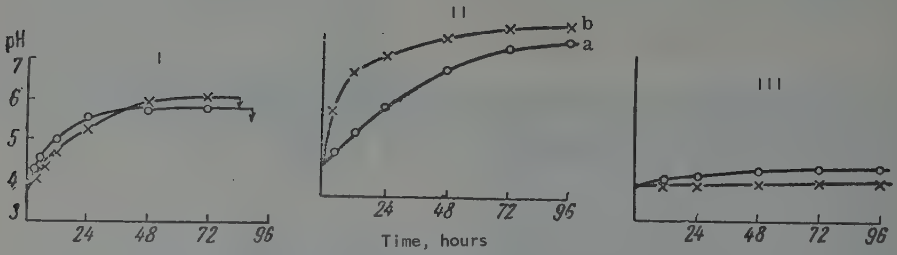


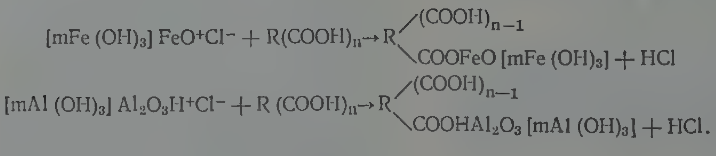
Fig. 1. The dynamic changes in pH value of humic acid sol.

I -- Ca saturated; II -- Na saturated; III -- Al saturated.

a -- askanite; b -- chernozem

the place of their formation. With shortage of calcium, the formation of acid humates of Ca is impossible and the movement of the latter to the lower horizons occurs. The fixation of Ca humates on the surface of the crystal lattice of clay minerals is caused by physical phenomena -- they adhere to the surfaces of these minerals in the process of dehydration and further condensation of humic acid molecules.

II. The reaction of humic acids or their soluble humates with non-silicate forms of aluminum and iron hydroxides is also of exchange nature. This process results in the formation of organo-mineral compounds of the complex salt type. The probable formula of their structure is shown below:



$$[mFe(OH)_3]\,FeO^+Cl^- + R(COOH)_n \rightarrow R\begin{array}{l}\diagup (COOH)_{n-1}\\ \diagdown COOFeO\,[mFe(OH)_3] + HCl\end{array}$$

$$[mAl(OH)_3]\,Al_2O_3H^+Cl^- + R(COOH)_n \rightarrow R\begin{array}{l}\diagup (COOH)_{n-1}\\ \diagdown COOHAl_2O_3\,[mAl(OH)_3] + HCl.\end{array}$$

We called these resulting products alumo- and iron-humic compounds (1). The study of the properties of these compounds, both in model preparations and in the process of fractional analysis of humic substances of various soils, revealed that their composition (the ratio between R_2O_3 and humic acid) is not constant due to the method of formation. The basic condition for their formation is the state of non-silicate sesquioxides. The compounds are formed within a wide pH range (from acid values to weakly alkaline) in the process of reaction of sols of both components, as well as in the reaction of sesquioxide sols with humic acid gels of any dehydration degree, or in the reaction of sesquioxide sols of humic acids and humates with fresh hydrated sesquioxide gels. They do not form in reactions of humic acids and humate sols with old, strongly dehydrated and, evidently, crystal forms of sesquioxides. Their most important property is the cation-exchange capacity at the expense of the residue of functional groups of humic acid that are not bonded to sesquioxides. This property determines their accumulation or migration within the soil depending upon the composition of exchangeable cations, the reaction of the medium, the degree of dehydration of these compounds and their relative content of R_2O_3. They accumulate in the soil when the residue of free functional groups becomes saturated with Ca, Al and H and move with the downward moisture flow when these groups are replaced with Na. They are easily peptized with weak alkaline solutions. The higher the degree of their dehydration, the firmer they are fixed in the soil. The universal role of exchangeable Ca in the accumulation of these compounds lies in the formation of gels that are not peptized in water.

What is their bond with the crystal lattice of clay minerals? It is the same as in the case of non-silicate sesquioxides. The majority of investigators consider the latter as films on the surface of minerals. Films form in the process of decomposition of primary and secondary minerals and in mineralization of vegetative residue; they undergo dehydration and crystallization, and are not chemically linked to the lattice surface.

onsequently, their fixation takes place in the ocess of dehydration when they adhere to e surface of the crystal lattice of clay mine- ls.

III. The answer to the question -- what is e linkage of humic acids and their deriva- es with the crystal lattice of clay minerals -- esents the greatest complications. Our cent research revealed that chemical bonds rough main valencies of components are sent.

The theoretical reasons for this deduction e present-day ideas on clay mineral struc- re. Both the crystal lattice of clay minerals d the macromolecule of humic acid are gatively charged. Prior to any interaction tween them, the existence of counter charged eas in the crystal lattice must be assumed; t Al located within octahedra is valence turated, and with its isomorphic substitu- on by Mg additional negative charges appear. similar picture develops when Si in tetrahe- a is replaced with Al. The possibility of netration of the macromolecule of humic id into interplane interstices of clay mine- ls is also unlikely because they are a nega- ely charged cation-exchange membrane. rthermore, according to the latest data of aig and Beutelspacher (12), the dimensions the humic acid molecule lie within the range 30-80 Å, while the dimensions between acings, even of montmorillonite clays that ell more than other clays, do not exceed -21 Å (4).

To study this question experimentally we epared samples of H-sols of askanite or a ineral fraction of chernozem colloids and mic acid.

Sols of mineral components were obtained the following manner: weighed samples of tural askanite and a mineral fraction of ernozem colloids[1] were electrodialyzed. ey were ground to the consistency of thick ste, water was added and the samples were ptized by 0.1 N NaOH to pH 8.5. The sulting suspension was centrifuged until rticles <0.1 in diameter were separated. e conversion into H-form was carried out the SBS cationic column in hydrogen form. e pH value of askanite sol was 3.8; that of ernozem mineral colloids, 4.6. The con- nt of humic acid in model preparations ried within the limits of 8-10%. The cation- change capacity at three values of pH was determined in preparations and the isotherm sorption of water vapors was recorded. In all model preparations, regardless of the degree of their dehydration, a complete additivity of cation-exchange capacity at all pH values (Table 1) was observed. Consequently, all functional groups of humic acid remained free and the interaction of components through main valencies did not take place. Results varied when the isotherms of water vapor sorption was obtained (Fig. 2). There was no additivity of sorption properties in relation to water vapors in preparations. The value obtained is below the calculated value in all parts of the curve. It is known that the sorption value is directly proportional to the surface area of the particles. The additivity of sorption of soil fractions varying in their particle size was experimentally demonstrated by Kuron (13). The decrease in sorption value in model preparations evidences the reduction of the total surface area in the preparations because of the cementing of clay mineral particles and humic acid. Similar sorption isotherms were obtained for colloids extracted from chernozem before and after removal of humus (Fig. 3).

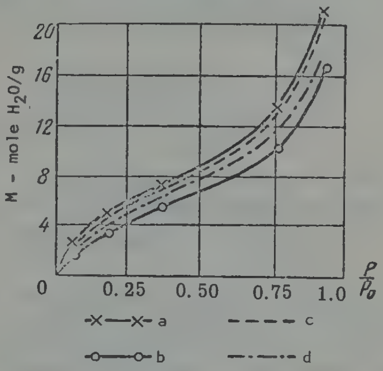


Fig. 2. Isotherm of sorption of water vapors by model preparations (askanite plus humic acid).

a -- askanite; b -- askanite plus humic acid (experiment); c -- askanite plus humic acid (calculation); d -- humic acid.

The data indicate that the fixation of humic acid and its derivatives on the crystal lattice surface of clay minerals is an adhesion phenomenon and is accomplished by van der Waals forces in the process of dehydration. Evidently, no less important are the hydrogen bonds causing the association of humic acid macromolecules and particles in the process of condensation of the aggregates. In this

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Colloids (<0.1 μ in diameter) were extracted om chernozem in a centerfuge according to K. Gedroits' method; their mineral fraction was tained by the oxidation of the dry sample with 10% lution of H_2O_2.

manner are formed the "bridges" of humic substances and their organo-mineral derivatives between the particles of mineral colloids; the concept of these bridges was introduced by Tyulin (9).

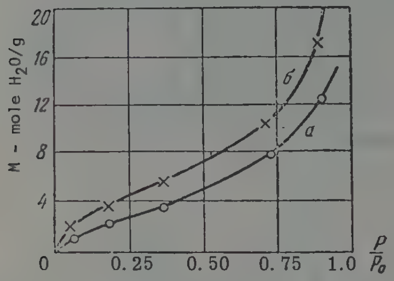

Fig. 3. Isotherm sorption of water vapors by chernozem colloids.

a -- original; b -- mineral

Thus, the organo-mineral colloids (from the chemical viewpoint they are not of organo-mineral nature) are a variable composition complex of highly dispersed minerals, humic substances, and alumino- and iron-humic derivatives in mixed aggregates. They are typical mutable compounds that form in the process of soil formation and disintegrate in its subsequent course. Their formation is the result of: 1) exchange reactions of humic substances with exchangeable cations resulting in the formation of various humates which are no bonded to the surface of the mineral lattices; 2) complex formation of humic substances and non-silicate forms of sesquioxides; also an exchange process leading to the formation of alumino- and iron-humic compounds; 3) adhesion of humic substances and their derivatives to the surface of crystal lattice of mineral accomplished by van der Waals forces and hydrogen bonds. Their composition and degre of accumulation and migration are determined by the soil formation process. The formation of chernozem, characterized by the accumulation of humic acids and clay minerals, the saturation with calcium and certain definite conditions of moisture supply, induces the maximum accumulation of organo-mineral colloids. However, in the formation of podzol soils, the accumulation of organo-mineral colloids is only concurrent with the development of sod in upper horizons because of the dominating role of crenic acids, and also the dispersion of colloids and shortage of calcium. Solonetz soil formation, owing to the dominating role of exchangeable sodium and alkaline

Table 1

Cation-exchange capacity of askanite and mineral colloid of chernozem and of their synthetic sample with humic acid in me per 100 g sample

Sample	pH		
	4.5	6.8	8.2
	Askanite		
A. Desiccated, finely ground . . .	85.8	96.5	99.6
B. Hydrated gel.	101.8	107.5	117.4
	Askanite plus humic acid		
A. Experimental	92.2	114.0	127.3
Calculated	93.6	113.9	121.6
B. Experimental	112.2	125.9	141.4
Calculated	115.3	126.7	141.5
	Mineral colloid of chernozem		
A. Dessicated, finely ground . . .	71.6	88.6	90.3
B. Hydrated gel.	74.2	90.0	100.2
	Mineral colloid plus humic acid		
A. Experimental	85.7	111.3	125.6
Calculated	83.5	112.4	120.4
B. Experimental	88.4	115.9	134.2
Calculated	95.0	117.0	133.9

action, facilitates the migration of organo-ineral colloids along the profile. Our con- pt of organo-mineral colloids explains their riable state and suggests the most rational ethods of their study.

Investigations by Nad' (7) showed that in y soil, colloids are not uniform in the rength of their adhesion. The use of the ethod of fractional peptization substantiates is contention (Table 2). Some colloids have e ability to move and can be peptized with edroits' method; others are less mobile and ditional pulverization and weak alkali solu- ons are necessary for their extraction.

Table 2

Amount of primary particles in chernozem and brown mountain-forest soil obtained in their fractional peptization, percent of dry soil

Soil	Diameter of particles, microns	Gedroits' method	Additional pulverization of particles >1 μ diameter	Additional peptization with 0.02 N NaOH of particles >0.1 μ diam.	Degree of colloid mobility (%)
Chernozem	>10	35.2	30.5	30.5	
	10-1	25.6	18.7	18.2	
	1-0.2	15.2	21.9	15.2	
	0.2-0.1	5.7	7.1	6.0	66.5
	<0.1	18.3	21.8	30.1	
Brown forest	>10	70.2	55.7	55.7	
	10-1	20.4	18.6	18.1	
	1-0.2	6.7	18.0	15.4	
	0.2-0.1	0.8	3.2	3.8	25.0
	<0.1	1.9	4.5	7.0	

e chemical composition of all colloids in il under study is practically uniform. The mus content varies within the range of -12%, the molecular ratio $SiO_2 : Al_2O_3$ in ernozem colloids is 3.8-3.1, while in lloids of brown forest soil it is 2.5-2.0. lly colloids obtained from surfaces of coarse rticles (>1 μ in diameter) are the main mus substances. Although these data fail corroborate Tyulin's latest concept (10) of dissimilar nature of colloids in two groups microaggregates, they agree with his earl- ideas (9) on the existence of colloidal ms of various densities on the surface of arse soil particles.

The study of organo-mineral colloids of l must provide for: 1) the determination of al amount and identification of their state the soil, and 2) the study of their composi- n. The first can be accomplished by our dified method of fractional peptization (7). us, a soil sample saturated with Na (following the Gedroits' method) is separated into not less than four fractions, >10 μ, 10-1 μ, 1-0.2 μ, and <0.2 μ in diameter. Colloids are extracted from each of the first three fractions by additional puddling and then by peptization with 0.02 N NaOH. Mobility can be conveniently expressed in percent to the total amount of colloids (e.g., in chernozem it is 66.5% and in brown forest soil, 25%). The composition of colloids (with the exception of those taken off the coarsest fraction >10 μ in diameter) is determined by the usual methods -- the mineralogical and chemical composition, the quantity of non-silicate R_2O_3, the composition of humus, etc. Also identified is the composition of adsorbed cations in soil.

It was necessary to introduce several corrections into the various interpretations of the humus data of fractional analysis performed in accordance with I. V. Tyurin's method. The existence in soil of three forms of humic substances -- humic acids, their salts with cations of strong bases, and alumino- and iron-humic sols -- is now proven. These substances can be either free or more or less firmly bonded or (to be more precise) aggregated with clay minerals. Fractional analysis does not reflect the forms of linkage of humic substances with the mineral fraction; it reflects the aggregating strength of the three forms of humic substances with the latter. The direct treatment of soil with 0.1 N of NaOH solution and, even more so, the treatment with 0.1 N of H_2SO_4 solution after decalcification disturbs, to a certain extent, the aggregation of the three groups of humic substances with the mineral fraction. The first treatment separates the least firmly aggregated humic substances, while the second and subsequent treatments separate more dehydrated and firmly linked groups. It is evident that the determination of the amount of sesquioxides in the sulfate filtrate proposed by Ponomareva (8) which depicts the specific features of the genesis of certain soils, does not ascertain the amount of sesquioxides linked with humic substances. These mobile forms of sesquioxides are always present in horizons that do not contain humus and also in parent material. They result from the concurrent development of the processes of weathering and soil formation and also the action of humic substances on the mineral fraction.

The use of 0.1 N solution of sodium pyrophosphate in fractional analysis, proposed by Brenner, yields good results. The fractional analysis should start with this treatment (rather than the treatment with 0.1 N of NaOH solution). Our research shows that pyrophosphate extracts all forms of free humic substances. Because of the formation of insoluble salts with Ca it completely extracts Ca humates and fulvates which are strongly aggregated with the soil mineral fraction. Moreover, and most important, it extracts free alumino- and iron-humic compounds without affecting non-silicate forms of sesquioxides. The determination of the quantities of Al and Fe in pyrophosphate filtrate provides the measure of the total amounts of alumino- and iron-humic compounds. At the present time, we are devising and checking the most efficient method of fractional analysis involving the use of pyrophosphate.

CONCLUSIONS

1. Organo-mineral colloids are a complex of variable composition of highly dispersed minerals, humic substances, and alumino- and iron-humic derivatives in the state of aggregation.

2. In any soil, colloids are not uniform in the degree of their mobility; some are found in a free state and some adhere to the surface of the coarser particles. The state of colloids is determined by the relative content, the degree of dehydration, and the composition of exchangeable cations.

3. The methods of studying colloids must provide for the determination of their total amount, their state, and their qualitative composition. The use of 0.1 N of sodium pyrophosphate solution in the fractional analysis of humus is recommended.

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SYNTHETIC SOIL CONDITIONERS

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The term synthetic soil conditioners refers mainly to organic compounds which improve he water stability of soil structure. The idea f soil conditioning is associated with A. F. offe and D. L. Talmud; it originated in the SSR in 1932.

We noted (5) that the forerunners of synhetic soil conditioners were the experiments f Fadeyer and Vil'yams that were designed o obtain a water stable soil structure by introducing humic substances extracted from hernozem into a mixture of soil and sand.

New ideas on synthetic soil conditioners ere based on a premise that humic acids 10) are not the only producers of water stability in soil structure. In 1934, the author eported the first results of his synthetic oil conditioner experiments to the All-Union Conference on Soil Physics. The findings ere based on new principles; they failed to mpress the soil scientists. Nevertheless, he Institute of Agrophysics continued the investigation. Prior to World War II, a variety f organic compounds were tested for their ggregating potential. The basic requirements of such compounds were solubility in ater, penetration into soil, reaction with oil and transition into the insoluble state ith subsequent adsorbtion by soil particles, nd ability to impart the properties of water tability on soil aggregates.

SUBSTANCES MEETING REQUIREMENTS

Cellulose. An industrial product - a viscous quid, cellulose xanthogenate (viscose) - $C_6H_9O_4OCSSNa$) which can be diluted by water as used for the experiments. Pure quartz ands of various degrees of dispersion (0. 5 - . 005 mm in diameter) were conditioned by iscose diluted in water; they acquired the roperties of water stability. Structureless oils with various degrees of podzolization nd viscose acquired the water stability of rdinary clay loam chernozems. Out yields on experimental field plots rose sharply in comparison with yield gains on plots with mineral fertilizers (6).

Hemicellulose. Xylane obtained by the Sal'kovskiy method which represented the hemicelluloses, was tested. Although xylane jells properly and imparts high mechanical stability to soil aggregates samples of pulverized sod-podzolic clay loams treated with xylane gel did not acquire the water stability of samples obtained by water. This is explained by the high water solubility of xylane. When considerable quantities of lime are placed in soil treated with xylane, the water solubility of xylane is lowered and soil aggregates acquire water stability (9).

Lignin. Because an assumption was made that lignin extracted by strong acids is vitally altered and bears a slight resemblance to natural lignin, the tested lignin was obtained by a less drastic method of Bekman and Lishe. This method involves the extraction of lignin from straw. Straw is treated either with 2% alcohol solution of caustic soda or with 1. 5% NaOH with the subsequent removal of carbohydrates by boiling with 2 - 2. 5% HC1, or precipitation with methyl or ethyl alcohol. After air drying, this type of lignin pulverizes and the powder is not soluble in water. It was introduced to soil in 1% solution of KOH. Samples of sod-podzolic clay loam treated by an alkali solution of lignin (0. 5% dry lignin in percent of soil weight) increased the content of water-stable aggregates (>0. 25 mm in diameter) from 51. 2 - 82. 6% (9).

Humic acid. Extracted from peat by the Sven-Oden method, humic acid was introduced to the soil in a 1% KOH solution. An equal dose of humic acid applied to the same soil produced an effect similar to that of lignin. Water-stable aggregates in the same sod-podzolic soil increased from 51. 2 - 81. 6% (9).

Bitumens. Bitumens were extracted from peat by treating it (by Stadnikov's method) with benzyl alcohol for 8 - 10 hours and the subsequent distillation of benzyl alcohol. They were introduced to soil in 1% KOH (8). Peat bitumen doses equal to those of lignin and humic acid increased the water-stable aggregates in samples of the same sod-podzolic soil from 51.2 - 85.8%.

The study of the soil structure-formation effect of various organic matter fractions led to the idea of using two industrial products, peat glue and glue made of plant residue, to improve the water stability of soil structure.

Peat glue. The following method is used: Add 1% KOH solution to dry semi-decomposed peats from lowlands, uplands or transition bogs in a 1:10 proportion of dry peat to the solution, and boil for 1 to 2 hours (after boiling starts). Cool the liquid, let it settle and pour (or drain through a ceramic filter) to a container. This transparent dark-brown liquid is called peat glue. The liquid (colloidal solution) extracted from upland peat contains 4 to 5% organic matter composed approximately as follows: water soluble fraction - 17.2%, soluble in benzyl alcohol - 19%, and humate fraction - 53.5%. Peat glue is introduced to soil in a liquid form. After moistening to desired depth the soil is dried to the optimum moisture for structure formation. After the moisture content is reached, the soil is tilled with cultivators, harrows or rakes, depending on the plot size. The resulting macroaggregates acquire water stability after drying. Peat glue dries easily (slow drying at temperature not over 60° C); its introduction in dry state to wet soil (preferably in spring) is simple. Laboratory and field tests involving various soils (mostly podzolic) demonstrated that 0.25, 0.5 doses of peat glue with 1% of dry matter to soil weight improve the water stability of soil aggregates. On fine clay loams and clays, the introduction of 1% peat glue yields 82 - 87% of water-stable aggregates; it approaches the condition of ordinary virgin chernozems of similar texture (Table 1).

Also positive were the results of field tests with different crops, as demonstrated by Kolyasev (6), Vershinin (1), and other researchers.

STRUCTURE-FORMING SUBSTANCES FROM PLANT RESIDUE (COMPLEX LIGNOHEMICELLULOSE SUBSTANCES)

Cementing substances from cotton and cane. Cotton and cane were boiled for 2 hours in 1% alkali solution in an autoclave under pressure of 2 atmospheres. The ratio of dry organic matter to water was 1:10. The resulting liquid, either "glue from cotton" or "glue from cane," was used as a structure-forming agent. Tests were conducted on sierozem clay loams. The "glue from cotton" exhibited better aggregating properties. The total of water-stable aggregates > 0.25 mm in diameter in field tests increased from 1.0 - 84.2%. However, they proved biologically unstable; by December (the experiment started in July), the same fractions decreased, correspondingly, to 0.5 and 7.7%

A similar method of preparation was applied to boiling cementing substances from geranium residue (Institute of Humid Subtropics of Sukhumi). These cementing substances have also positively improved the water stability of soil structure. When these substances were introduced to Sukhumi podzolic clay loams, the water-stable aggregates in soil rose from 41.0 - 76.0%

Resin glue. Resin structure-forming substances differ considerably from those described previously. They differ in the effect on physical properties of soil and in the quantity needed. Resin cementing substances were obtained from cheaper grades of resin soap or from industrial colophony. Colophony comprises a complex of resin acids with a predominance of abietinic acid ($C_{20}H_{30}O_2$). Abietinic acid of colophony is not soluble in water, but the solubility of potassium and sodium soaps is good. Following the saponification of colophony (by saponification number) we obtained the so-called resin glue which can be placed in soil either in aquerous solution of desired concentration, or powder. When an amount comprising 0.05% of soil weight was added to soil, it increased the water stability of the aggregate 3 mm in diameter of sod-podzolic clay loam from 3.8 - 49.7%. A dose of 0.1% on the same soil raised the amount of water-stable aggregates to 88.0%. A specific feature of these structure-forming agents is the reduction in hydrophilic property of soil. However, numerous field tests involving sod-podzolic zonal soils, always indicate increases in the yield of various agricultural crops when these substances are applied in certain doses (4, 5). Table 2 represents a compilation of field experiment data to ascertain the dosage of sodium abietate for raising barley yields. The tests, conducted by Ya. A. Kovalev in 1938, involved sod-podzolic soil from an experimental field of the Leningrad Agricultural Institute. The size of the plot's area was 40 sq meters. The control and variants of the experiment received $N_{75}P_{75}K_{75}$. Table 2 shows the 200 kg/ha dose of resin as the best one.

Table 1

Structural forming capacity of peat glue

Soil	Quantity of peat glue, % of soil wt	Total amt. of water-stable aggregates >0.25 mm in diameter, %
Sod-podzolic gley clay	0	38.2
" " "	0.5	68.2
" " "	1.0	82.0
Sod-podzolic clay loam	0	64.9
" " "	0.5	71.1
" " "	1.0	77.1
Sod-gley clay	0	58.8
" "	0.25	77.1
" "	0.50	84.0
" "	1.0	87.6

Table 2

Effect of sodium abietate on barley yield

Glue application, kg/ha	Average wt of four replicates, kg per plot		Calculated on hectare basis		Increase, %	
	Grain	Straw	Grain	Straw	Grain	Straw
0	12,8	14,6	32,0	38,5	0	0
10	13,3	15,8	34,3	39,5	7,2	2,6
50	14,1	17,1	35,3	42,8	10,3	11,3
200	14,8	16,0	37,0	40,0	15,6	4,0
1000	14,8	19,1	37,0	47,8	15,6	24,2
2500	14,2	17,6	35,5	44,0	10,9	14,3

Note: Comma represents decimal point.

INTERACTION OF STRUCTURE-FORMING SUBSTANCES WITH SOIL

Omitting the historical details concerning the views on interaction between structure-forming agents and soil we shall sum up certain findings. Two problems were considered in the past: 1) the interaction of structure-forming substances with mineral soil particles, and 2) the reaction of molecules in the structure-forming substances. The interactions of the substances and soil were treated as surface phenomena. Cementing agents had to be adsorbed by soil particles and retained on soil surfaces by intermolecular (van der Waal's) forces. The mechanics were assumed to be as follows: a double ionic layer is found between molecules of the structure-forming substances and the surface of the mineral particles of soil. The external layer of ions (cations) inhibits the effect of cohesion forces between molecules of structure-forming substance and soil particles; it stands in their way and acts as a repelling force. The greater the hydration of ions of the diffusion layer, the further is their repelling of structure-forming molecules from the surface of soil particles. However, the hydrated shell of ions disintegrates in the process of soil drying and the forces of cohesion between structure-forming molecules and soil particles become stronger. Finally, the van der Waal's forces of attraction become stronger than the repelling forces of ion and the structure-forming substances being retained by intermolecular bonds are adsorbed by soil. The ion effects of the double layer are not only electrostatic; their chemical affinity to cementing substances and the mineral fraction of soil is also important.

We stated previously, that all structure-forming substances must be dissolved in water and penetrate the soil easily and be adsorbed by its mineral particles. Hence, there are two tenets: a) the surface of soil must be treated as the reacting surface, b) structure-forming substance must produce a better effect on the formation of soil structure when applied in a quantity equal to the monomolecular covering of the surface by the cementing substance. If we assume that the surface area of 1 gram of fine clay loam amounts to approximately 10^5 cm^2, while the thickness of the monomolecular layer, as measured by Wedekind and Katz (23) is about 10^{-7} cm, in the case of lignin, the volume of substance on 1 gram of soil will amount to $10^5 cm^2 x 10^{-7} cm = 10^{-2} cm^3$. Alternatively, assuming the specific gravity of humic acid and similar substances to be 1. 3, we obtain $10^{-2} cm^3$ x 1. 3 = 0. 013 g or 1. 34 of the soil weight. The humic and similar substances mentioned previously actually exert a good aggregating effect when applied in a quantity of approximately 1% of the soil weight. Abietinic substances produce aggregating effects in smaller quantities. However, their monomolecular layer is correspondingly thinner.

The intermolecular reaction of cementing substances is also important in the process of their transition in the soil to the insoluble state. They form a film which cements soil particles and protects them from the destructive action of water. In most cases, the transition from soluble to the insoluble state is effected by polymerization reaction involving the participation of either hydrogen bonds or bonds at the expense of basic valence forces.

In this connection, the previously mentioned structure-forming substances can be classified into two types from the viewpoint of their transition into the insoluble state: 1) Substances which become insoluble only by exchange reactions with soil, and 2) substances which become insoluble independently of exchange reactions with soil.

Humates and similar substances are of the first type. Also included in this type are all substances applied to soil in the form of soluble soaps; for example:

$$\text{Soil Colloid } H^+ + K^+ \text{ Humate} = \text{Soil Colloid } K^+ + H^+ \text{ Humate}$$

Potassium humate is converted into humic acid as a result of exchange with the soil sorbing complex. We demonstrated (3) that humic acid is converted into water-insoluble gel after a certain amount of water is lost. Similar reactions occur with potassium and sodium abietates. Evidently, it is important in this case for exchangeable cations to form insoluble compounds in their reaction with molecules of cementing substances.

Viscose belongs to the second type. Under the effect of carbon dioxide of air it can change independently of exchange reaction with soil to insoluble cellulose.

Kriliums. Foreign periodicals, particularly American, exhibited considerable interest in synthetic structure-formers (without mentioning our research) in the course of most recent years. Attention was drawn to various structure-forming substances:[1] salts of polyuronic acids and polysaccharide derivatives, derivatives of cellulose (methylcellulose), sodium silicate, silicoorganic compounds (dimethyldichlorsilane), stearic, alginic, and abietic acids. Postwar American literature contained numerous proposals on structure-forming substances; these were repetitions of our 1932-1936 research.

In 1951, several large commercial firms became interested in a somewhat different type of soil conditioner. After many years of laboratory and field research, the Monsanto Chemical Company came out with derivatives of polyacrylic acids as soil conditioners. They became known under a collective name "kriliums". Two soil conditioners were placed on the market: CRD = 186 (a copolymer of vinyl acetate and maleic acid) and CRD = 189 (hydrolyzed polyacrylonitrile). In 1952, various firms offered several structure-forming substances named "Polyac," "Fluffium," "Aerotil" and "Loxar." Information or Kriliums began to appear in European press and in several countries (Belgium, France, West Germany, German Democratic Republic, Hungarian People's Republic, Italy, England, etc). American kriliums were studied and new ones produced locally. However, up to the present time, the previously mentioned American kriliums developed by the Monsanto Company were the most popular ones. Frequently, they are now known under the names of VAMA (vinylacetate of maleic acid) and HPAN (hydrolyzed polyacrylonitrile).

The first publications of Hedrick and Mowry (18), Allison (13), Martin, Taylor (20), Ruehrwein and Ward (22) contained considerable information on the substances. Their data show that kriliums exert a full effect of aggregation when applied to soils in a quantity of 0. 1% of the soil weight. Even if the soil conditioner quantities are 0. 05% and 0. 02%, the results may be good for some soils. The effect of aggregation on solonetzic soils is even more pronounced. The hydrophilic property of soil is not lowered by kriliums. Its application increases many agricultural crop yields. The decomposition of kriliums by microorganisms is not too strong and the water stability of aggregates which they create is retained for several years.

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[1] See: Soil Sci. Soc. America Proc. v. 10, p. 450, 1945; J. Amer. Soc. Agron. v. 38, p. 95, 1946; J. Agric. Sci. v. 37, p. 257, 1947 and other journals.

Kriliums are typical polymers used mainly in industry for various purposes (plastics, varnishes, organic glass, etc). Their basic link is the original monomer. For acrylic acid, it is CH_2 = CH -- COOH with molecular weight 72.06; for metacrylic acid, it is CH_2 = C - CH_3 - COOH with molecular weight 86.09; for maleic acid, it is COOH - CH = CH - COOH with molecular weight 116.07.

In polymerization, which is usually effected by catalysts, individual links (monomers) begin to join and form long chains. The number which indicates how many times a given link is repeated in the chain in the polymerization coefficient. Polymeric chains of different chemical structures may join to form a copolymer. A polymer of acrylic acid is known as polyacrylic acid, that of metacrylic acid -- as polymetacrylic acid, etc. Each link has one or another active group: carboxyl amide, nitrile, etc. Polyacrylamide will be formed if the carboxyl group in acrylic acid is replaced by an amide group. If replaced by a nitrile group, the resulting product will be polyacrylonitrile, etc. Polymerization is usually connected with the loosening of double bonds which activate the molecules; the latter gain the ability to react with each other. In copolymers, the number of active groups per unit of substance weight is higher than in polymers.

What did the use of polymers contribute to the theory of structure-formation? We stated that the formation of water-stable aggregates requires a smaller quantity of polymers than that of humic substances (approximately only about one-tenth). Using resin glues we obtained similar quantities of cementing substances which cause complete aggregation. But kriliums differ from resin glues because they fail to lower the hydrophilic properties of soil. The water stability created by these substances only slightly depends on the adsorption complex. Sodium saturated soils, as shown by Allison (14), even increase the aggregating effect of VAMA and HPAN kriliums. The reaction of polymers with soil occurs on the surface of soil particles.

In applying equal quantities of soil conditioners the aggregating effect weakens with increases in the quantity of clay particles in the soil. This was demonstrated on mixtures of sand with clay minerals (kaolinite, and montmorillonite in the form of bentonite) by Hagin and Bodman (17) and confirmed by Allison for several soils. Hagin and Bodman link this phenomenon with the dimensions of the specific soil surface, as shown in Fig. 1 reproduced from their report. Ruehrwein and Ward (22) think that the mechanism of structure formation caused by polymers is in the nature of coagulation, polymers are typical polyanions or polycations. Polymers enter among the soil particles and coagulate them.

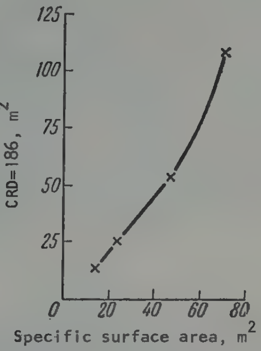

Fig. 1. Minimum amounts of CRD = 186 required for a complete aggregation in relation to specific surface area (17).

Montgomery and Hibbard (21) made an interesting attempt to connect the physical chemical properties of kriliums (which are high molecular polymers) with soil conditions. They came to a conclusion that the activity of polymers (i. e., their structure-forming properties) in soil depends on their "functionality" ("functionality" is understood as the ratio of active groups in repeating chains to the total weight of polymer's activity in soil is increased with increases in "functionality." It reaches a maximum and drops regardless of increases in "functionality." When "functionality" is low, the number of active groups is not sufficient for linkage with soil particles; but in a high "functionality," the activity of groups is considerable, as evidenced by the polymer's solubility in water.

With increases in the polymer's molecular weight its activity in soil rises rapidly to an optimum value; its subsequent decrease is connected with the polymer's viscosity and ability to be adsorbed by soil particles. Tests with sulfonated polystyrene established a close relationship between the polymer's activity in soil and the number of sulfonal crosslinks in molecular chains. The activity decreases with increases in the number of crosslinks.

The relative strengths of the soil-amide, soil-carboxyl, and soil-sulfonic acid bonds are, respectively, 1.6 : 1.0 : 0.8. Evidently, a hydrogen bond between polymers and soil particles is involved. Emerson (15), using the measurements of French and others (16) who demonstrated by infrared spectroscopy an increase of hydrogen bonds when CRD = 186 was added to montmorillonite, believes that hydrogen bonds (vertical and lateral bridges) are formed between polymers and clay minerals. He also believes that polymers are more effective when the bridges are lateral. Holmes and Toth (19) refer to the existence of hydrogen bonds between clay particles and a polymer. They drew this conclusion on the basis of infrared radiation spectra of kaolinite, monmorillonite and illite treated with S-17 polymer (half-amide and half-ammonia salts of the copolymer of methylvinyl ether and maleic acid).

We tested several kriliums produced in the USSR. Testing polyacrylonitrile on sod-podzolic clay loam yielded the following results: the application of polyacrylonitrile in a quantity of 0.1% of the soil weight, brought the number of water-stable aggregates > 0.25 mm in diameter to 95-96%; their number in the control soil sample was 26.5%. When aggregates obtained by application of polyacrylonitrile were pulverized and newly aggregated under the moisture conditions of structure formation they regained their water stability. In this case, the percentage of water-stable aggregates was 93.5. Thus, polyacrylonitrile restores the water stability in aggregates after the mechanical destruction of aggregates. We know that numerous polymers have the property of restoring polymeric chains after mechanical destruction.

Polyacrylonitrile is adsorbed by soil. For this experiment, we used 100 grams of the same soil and 500 grams of polyacrylonitrile solution of various concentrations. Figure 2 shows the adsorption of polyacrylonitrile by sod-podzolic clay loam which appears as a linear function of concentration.

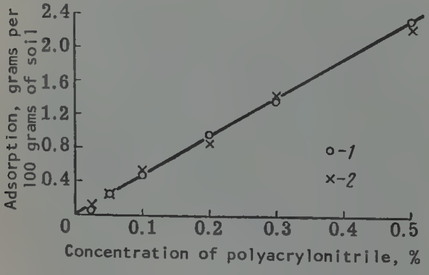

Fig. 2. Adsorption of polyacrylonitrile from solutions by sod-podzolic clay loam. Ratio of soil to solution 1:5

1 -- Original experiment; 2 -- repeated.

We are convinced by the recent-year experiments with soil conditioners that the relatively large amounts of humate-type soil conditioners which are necessary for soil structuring impede their practical use. Consequently, we were particularly interested in decreasing the quantity required for aggregation in our experiments with kriliums. We conducted several elementary experiments jointly with the Institute of High Molecular Compounds of the USSR Academy of Sciences. The monomer of meta-acrylic acid is soluble in water. Its conversion to a polymer calls for certain conditions, specifically for the introduction of a catalyst. The polymer of metacrylic acid (polymetacrylic acid) is insoluble in water. In our experiments, the number of water-stable aggregates in sod-podzolic clay loam increased from 22 - 75% when a quantity (0.1% of soil weight) of the monomer of metacrylic acid was introduced to the soil. Consequently, the sod-podzolic clay loam serves as a catalyst; it converts the monomeric metacrylic acid into polymeric. The structure-forming properties of metacrylic acid were enhanced by its polymerization with metacrylamide. The effect of one of the copolymers (N VIII) composed of metacrylic acid (60%) and metacrylamide (40% on the water-stability of the same sod-podzolic clay loam is presented in Table 3.

It follows from the table's figures that this copolymer, even when introduced in a quantity comprising only 0.001% of the soil weight, serves to improve considerably the water stability of aggregates. As the quantities of introduced cementing substances are negligible, we may deduce that the origin of water stability cannot be explained by the theory of monomolecular covering of the surface of soil particles. Evidently, the mechanism of cementing the particles by polymer is not the one mentioned in the case of the humate-type structure-forming substances. Thus, the assumed existence of chemical bonds between the polymer and clay particles has an adequate foundation.

Let us proceed with a simple calculation and assume that the molecular weight of 1 copolymer link is about 200; then the total number of monomeric links in 1 gram of the copolymer will be:

$$\frac{6.06 \times 10^{23}}{200} = 3.03 \times 10^{21}$$

If the polymerization coefficient is taken as ≈ 15,000 (which approximates the value for kriliums given by Emerson), the number of chains in 1 gram will be:

$$\frac{3.03 \times 10^{21}}{1.510^{4}} = 2 \times 10^{17}$$

Table 3

Effect of copolymer of metacrylic acid and metacrylamide on the water-stable aggregates from sod-podzolic clay loam

Amount of applied copolymer, % of soil wt	Amount of water-stable aggregates >0.25 mm in diameter, % of soil wt
0.1	92.0
0.05	90.2
0.01	86.0
0.005	56.8
0.001	51.8
0	18.4

Table 4

Effect of the number of percolations on water-stable aggregates of sod-podzolic clay loam

Copolymer	No. of percolations with the same concent.	Quantity of copolymer added to soil, % of soil wt	Amount of water-stable ag. >0.25 mm in diam., %
Copolymer (VIII) of metacrylic acid and metacrylamide	1	0.001	51.8
	2	0.002	80.6
	3	0.003	81.4
	4	0.004	87.4

ur minimum dose of 0.001% (or 10^{-5}) has x 10^{17} x 10^{-5} = 2 x 10^{12} chains. An approximate count of the particles in 1 gram by par- cle size analysis yields a value cost to$\approx$10^{2}. 'he cementing of soil by 0.001% polymer dose ields approximately 1 polymer chain per par- icle. It appears that the result in this case hould be a complete aggregate of the soil. lowever, it does not happen.

Consequently, in the polymer's reaction ith soils the principal role is played not only y the specific soil surface as assumed by lagin, Bodman, and Allison but also by the orosity of soil. The smaller the pores, the nore "difficult" the penetration of polymer hains into the pores; the soil screens them cting as a sieve. Therefore, the development of methods for the introduction of polymer to soil is an important task.

When the polymer penetrates the soil the istribution of chains among soil particles is ot perfectly even. Therefore, mixing and epeated penetration must raise the polymer's fficacy. This is demonstrated by data of 'able 4.

The data indicate that repeated penetrations by the copolymer in a quantity comprising 0.001% of soil weight improved the water stability of aggregates (cf Table 3). Calculations show that the quantity of polymer applied to a hectare with a plow layer depth of 20 cm and bulk density of 1.0 gms/cc amounts to only 40 kgs. There is no doubt that these methods of improving soil structure have a great future.

CONCLUSIONS

Twenty-six years ago, several organic compounds were suggested at the Institute of Agrophysics for the improvement of soil structure. However, the amount of these substances required for obtaining good aggregation was quite large; this constituted the main obstacle to their practical utilization. After the war, new structure-forming substances of the high molecular polymer type were developed in the U.S. They comprised mainly the derivatives of acrylic, metacrylic, and maleic acids. The substances could be applied for aggregation in considerably smaller quantities - only 1/10 or 1/20 of the quantities required for humates and similar substances.

The study of reactions of polymers with soil particles and the methods of their application will provide an opportunity for the development of substances which could accomplish complete aggregation of soil in quantities not exceeding several tens of kilograms per hectare.

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EFFECT OF SOIL LIMING ON PHOSPHORUS ASSIMILATION BY PLANTS

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Superphosphate is a universal form of phosphate fertilizer. On leached and podzolized soils (podzolized chernozems, sod-podzolic soils, krasnozems, etc.) ground rock phosphate can be successfully used. When applied to the soil water-soluble phosphorus compounds in superphosphate rapidly change to water-insoluble forms, evidently to more basic calcium phosphates (in neutral and calcareous soils) or into high basic iron and aluminum phosphates (on soils with acid reaction). In these changes the availability to plants of soluble and semi-soluble phosphates applied to the soil (superphosphate, dicalcium phosphate dihydrate, etc.) is usually somewhat reduced. Ground rock phosphate with its low solubility in water also undergoes several changes in the soil. When rock phosphate is incorporated with acid soils, its solubility increases at first but recrystallization of phosphorus from the solution takes place simultaneously.

Several methods have been proposed to prevent absorption by the soil of phosphorus from superphosphate in forms of low availability for plants. These methods are: placing this fertilizer directly into the rows and hills where the plants are sown, its application together with organic fertilizers, preliminary liming of acid soils and combined application of superphosphate with lime. Under such conditions the amount of lime necessarily varies with the degree of soil acidity, capacity of the soil to adsorb phosphorus in a form almost unavailable to plants, and the form of the phosphates used. It is therefore important to determine the amounts of lime that have a positive effect on the availability to plants of various forms of calcium phosphate incorporated with the soil in different ways (placement, hill method, plowing under, etc.).

It is also known that liming increases the uptake of soil phosphates by plants. To elucidate the mechanism of this positive action of lime is of interest. Several explanations can be suggested: 1) lime acts as a factor to convert mineral or organic forms of soil phosphates into forms that are more available to plants; 2) lime improves the physicochemical and biological properties of soil as a medium for plant growth, thus raising the degree of assimilation of soil phosphates by plants.

We used the radioisotope method to ascertain the degree of assimilation of soil phosphates in relation to the method of application of the fertilizer and to determine the total amount of available phosphates in the soil. The soil was labeled with $Na_2HP^{32}0_4$ solution, with an insignificantly small amount of phosphorus contained therein (0.5 mg of P_2O_5 per vessel), but with a very high degree of activity (55 μc per vessel on June 20, 1957).[1]

In using a radioactive isotope of phosphorus to label the soil phosphates we made the following basic assumptions: 1) the adsorption of phosphate-ions by the soil and the reaction of isotope exchange proceed very rapidly and a few days before the vessels are filled all the radioactive phosphorus will become part of the soil phosphates most available to and assimilable by plants (1, 2); 2) the radioactive phosphorus isotope will be evenly distributed throughout the assimilable soil phosphates and will enter plants in proportion to its content in this amount of phosphates. A knowledge of the general activity of P^{32} added to the vessel, activity of P^{32} in the crop, and amount of total phosphorus in the crop makes it possible to determine the soil content of available phosphates from the following equation:

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[1] For a description of this method see A. V. Sokolov's article (4).

$$X = \frac{P \times 100}{K}, \qquad (1)$$

where X is the quantity of available phosphorus in the total soil of the vessel that is to be determined; P is the quantity of phosphorus in the crop which was taken up from the soil (as determined by chemical analysis of the plants); K is the percent of assimilation of P^{32} by the plants (the ratio of P^{32} activity in the crop to the total activity of P^{32} added to the vessel).

To study the effect of liming soil with an acid reaction on changes in the availability to plants of soil and fertilizer phosphorus, we ran pot experiments in 1957 on strongly acid sod-podzolic medium clay loam, the physical and chemical properties of which are presented in Table 1.

The experiment was set up in 15 x 20 cm glass vessels containing 3 kg of air-dry soil. The arrangement of the experiment is shown in Table 2. We added as basic fertilizer to each vessel 1 g N and 0.75 g K_2O as solutions of NH_4NO_3 and KNO_3 which were mixed into the soil. In vessels in which the soil phosphates "were tagged" we placed a solution of radioactive phosphate dissolved in the total amount of water used in filling the vessels. The soil was thoroughly mixed with the solution, it was then allowed to stand uncovered and was then packed into the vessels in accordance with the arrangement of the experiment.

As phosphorus fertilizers we used calcium phosphates of varying basicity: superphosphate containing calcium monophosphate and ground rock phosphate and a composition including a high basic calcium phosphate of apatite structure. Tracer superphosphate prepared by treating ordinary powdered superphosphate with an Na_2HOP_4 solution containing radiophosphorus[1] was used in the experiment. The specific activity of the superphosphate was 0.27 μc per mg. P_2O_5, while the overall activity was μc per vessel (June 20, 1957). The activity of P^{32} in the crop was determined in samples of dry plant matter weighing 0.2 g. From these figures the activity was converted to the content of P^{32} in the entire dry mass of the crop of each vessel. The content of the labeled phosphorus in plants expressed in milligrams of P_2O_5 per vessel was determined from the specific activity of labeled superphosphate used in the experiment. In liming the soil we used $CaCO_3$ obtained by precipitation from calcium nitrate when treated with a solution of ammonium carbonate.

According to the arrangement of the experiment, lime and phosphate fertilizers were placed locally in some vessels, in others they were mixed with all the soil. In local application the lime and phosphates were mixed only with the 100-g layer, while the rest of the soil was left without lime and fertilizer. In this experimental treatment the incorporation of lime and phosphates with the soil was done in the following manner: first 100 g of soil were limed at the rate of 0.66 g of $CaCO_3$ for this batch (which

Table 1

Chemical properties of sod-podzolic medium clay loam in the Dolgoprudnoye experimental field (1 crop rotation)

Exchangeable acidity (according to Sokolov's method)			Hydrolytic acidity (with coefficient of 1.75)	pH of soil suspension		Adsorbed cations, meq		Free phosphorus in mg of P_2O_5 as determined by methods of:			
Total	Free H^+	Free Al		KCl	H_2O	Ca	Mg	Egner	Chirikov	Kirsanov	By adding tagged P^{32} to soil[a]
Per 100 g of air-dry soil											
1.9	0.04	1.86	6.6	3.9	4.9	3.9	1.5	1.5	1.4	4.0	6.8

[a] For greater detail see below.

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[1] For details of the method of preparation see Klechkovskiy's and Kashirkina's article (3).

Table 2

Effect of liming on the uptake by plants of phosphorus from soil and fertilizers. Pot experiment, sod-podzolic soil.

Experimental treatment	Arrangement of the experiment, phosphates and lime after NK (S)[a]	Added to vessel		Method of applying fertilizers	pH of soil suspension		Weight of dry mass of crop, g	Uptake by plants, mg of P_2O_5			% of uptake of P^{32} in the experiment		Available soil phosphorus, mg of P_2O_5 per 100 g of soil	Content of labeled phosphorus assimilated by the plants from fertilizer as % of total quantity of phosphorus in the plant
		P_2O_5, mg	$CaCO_3$ g		KCl	H_2O		Total[b]	Including		From fertilizers	From soil phosphates		
									From fertilizers	From soil				
I	S*	--	--	--	3.9	4.9	3.3	4.0	--	4.0	--	2	6.8	--
II	S + $CaCO_3$	--	0.66	Placement	6.2	7.0	3.3	3.5	--	3.5	--	--	--	--
III	S + P_c^*	105	--	"	3.5	4.3	12.1	26.9	17.9	9.0	17.1	--	--	67
	S* + P_c	105	--	"			12.7	29.3	19.0	10.3	--	4.9	7.0	--
IV	S + P_c^* + $CaCO_3$	105	0.66	"	6.2	6.6	16.6	34.1	26.4	7.7	25.2	--	--	77
V	S* + $CaCO_3$ (1/2 of hydrolytic acidity)	--	4.65	Uniformly	5.0	5.9	6.0	14.9	--	14.9	--	7.4	6.7	--
VI	S + P_c^*	105	--	"	3.9	4.9	6.8	14.8	6.1	8.7	5.8	--	--	41
	S* + P_c	105	--	"			7.2	15.0	6.4	8.6	--	4.2	6.8	--
VII	S + P_c^* + $CaCO_3$ (1/2 of hydrolytic acidity)	105	4.65	"	4.9	5.9	10.6	37.0	14.9	22.1	14.2	--	--	40
VIII	S* + Pbackground	125	--	Placement	4.6	5.1	12.1	26.8	19.4	7.4[c]	--	3.7	--	--
IX	S + Pbackground + $CaCO_3$	125	0.66	"	6.4	7.0	4.1	11.8	--	--	--	--	--	--

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[a] S - soil of the vessel + background (NK); S*- soil of the vessel + background (NK) + P^{32}.

[b] Upon subtracting the uptake of P_2O_5 from seeds = 5 mg.

[c] See below for the computation of this value. The error in the experiment ± 0.6 g.

corresponds approximately to 6.6 ctnr/ha of $CaCO_3$). To the limed batch either 105 mg of P_2O_5 superphosphate or 125 mg of P_2O_5 in the form of ground rock phosphate were added in each vessel (the first amount corresponds approximately to 105 kg/ha of P_2O_5 and the second -- to 125 kg/ha of P_2O_5). The fertilized layer was placed 6 cm from the surface of the soil in the vessel. In cases when the lime and phosphates were mixed with the whole volume of soil in the vessel, the amount of calcium carbonate was applied at the rate of one-half the value of hydrolytic acidity, i.e., 4.65 g of $CaCO_3$ per vessel (which corresponds to 4.65 tons/ha of $CaCO_3$). The pH values reached when the lime and phosphates were applied to the soil at the beginning of the experiment are presented in Table 2. In cases of fertilizer placement the pH values refer only to the limed and fertilized layer.

Seven corn seedlings of the Krasnodar 1/49 variety were planted per vessel on June 19th. After thinning, four plants were left in each vessel. The green crop was harvested on August 19th. Soil moisture during the first month of the growing period was maintained at 60% and during the second month at 70% of the full moisture capacity.

It is evident from data in Table 2 on yield and phosphorus uptake by the plants that superphosphate added to the soil simultaneously with liming, both placed and uniformly distributed in the vessel, raised the yield. The application of ground rock phosphate simultaneously with lime reduced the yield to a value approaching that of the control. Because the experiment was set up with labeled superphosphate, we were able to determine the uptake of phosphorus by the plants both from the fertilizers and from the soil without using the conventional quite tenuous "differentiation method."

Phosphorus uptake by the plants from phosphorus fertilizers to which lime was added differed from the uptake when phosphates alone (without lime) were applied. Furthermore, in this case admixture of lime not only increased the yield (16.6 instead of 12.7 and 10.6 instead of 6.8 g) but also markedly raised the coefficient of assimilation of superphosphate from 17 - 25% in the case of local application, and from 6 - 14% when the fertilizers were mixed with all the soil in the vessel. When ground rock phosphate was applied to the soil together with $CaCO_3$, reduction in yield was accompanied by a decrease in the accumulation of phosphorus by the plants.

The uptake of phosphorus from the soil by the plants was quite diverse in the treatments of the experiment. After placement application of superphosphate alone or superphosphate with lime the uptake of soil phosphorus was almost identical and came fairly close to the uptake of P_2O_5 by plants in the control treatment (9 and 7.7 mg, control -- 4 mg of P_2O_5), but when superphosphate was mixed in the vessel with all the soil, limed at the rate of half the amount of hydrolytic acidity, the uptake of soil phosphorus sharply increased (up to 22 mg against 8.7 mg when superphosphate was applied to unlimed soil). When lime alone was dispersed throughout the vessel at the rate of half the amount of hydrolytic acidity, the uptake of phosphorus from the soil was also substantial (14.9 mg of P_2O_5 per vessel).

It will be noted that the placement application of superphosphate only and of superphosphate with a little $CaCO_3$ caused the plants to assimilate phosphorus mostly from the fertilizers (67% and 77%, respectively, taking as 100 the total uptake of phosphorus both from the soil and from the fertilizers). On the other hand, when superphosphate was mixed throughout the soil, limed and without lime, the uptake of phosphorus was mostly from the soil (60% from the soil and 40% from the fertilizers). Table 2 contains data on phosphorus uptake from the soil and from ground rock phosphate. Since the rock phosphate used in the experiment was not labeled, it was impossible to obtain these data directly. For this reason the values for phosphorus uptake from the soil and from rock phosphate were calculated separately, as will be described below.

Besides determining the soil phosphorus uptake, we were also able to observe the way the assimilation of phosphorus from the soil changed when fertilizers (superphosphate, rock phosphate, $CaCO_3$) were placed in the vessel. We also succeeded in determining the total available phosphates in the soil. Table 2 shows that the degree of soil phosphate assimilation varies widely with the use of different fertilizers. The smallest uptake of soil phosphorus, amounting to 2% of the total quantity of available phosphates in the soil, took place in the control sample -- NK. When superphosphate was applied to the soil, the degree of assimilation of soil phosphorus increased to 4.2% (when superphosphate was mixed throughout the vessel) and 4.9% (with placement application of superphosphate).

The greatest uptake of phosphorus took place when the soil was limed at a value of half the hydrolytic acidity -- 7.4% of the total content of available phosphates in the soil. By knowing the amount of phosphorus uptake and the percent of assimilation of P^{32} under the conditions of the experiment, we were able to determine the amount of the available phosphorus by using the equation (1):

$$X = \frac{P \times 100}{K}$$

For instance, for variant VI (S + Pc "uniformly") (Table 2) the degree of assimilation of available soil phosphates is 4.2%. The plants extracted from the soil 8.6 mg of P_2O_5; hence, the total amount of available phosphates in the soil is:

$$X = \frac{8.6 \cdot 100}{4.2} =$$

204 mg of P_2O_5 per vessel or 6.8 mg of P_2O_5 per 100 g of soil.

It is evident from these computations that the quantity of P_2O_5 introduced into the soil together with fertilizers was excluded from the total amount of available phosphorus in the soil. In all experimental treatments the total amount of available phosphorus in the soil was almost identical and averaged 200 mg of P_2O_5 per vessel or 6.8 mg of P_2O_5 per 100 g of soil (see Table 2).

In those vessels where ground rock phosphate and radioactive phosphorus were placed for the purpose of labeling soil phosphates, the amount of phosphorus assimilated by the plants from rock phosphate was determined by the following calculations. The uptake of soil phosphorus for a given treatment was 3.7% of the total amount of available phosphates. We took the total amount of available phosphorus in the soil as 200 mg of P_2O_5 per vessel. Hence, 7.4 mg of P_2O_5 were extracted from the soil and the remainder from the seeds and fertilizers. Corn seeds contained 5.8 mg of P_2O_5 (the assimilation of phosphorus from seeds amounted to about 90% and was taken by us as 5 mg). The difference between 31.8 mg of P_2O_5 (total uptake of phosphorus by plants per vessel) and 12.4 mg of P_2O_5 (uptake of phosphorus by plants from soil and seeds) comprised 19.4 mg of P_2O_5 which, it can be assumed, came from ground rock phosphate. The rock phosphate was applied locally and therefore the direct contact between it and the radioactive phosphate was considerably reduced. For this reason it can be assumed that P_2O_5 of ground phosphate played an unimportant part in the isotope exchange and that the P^{32} tracer came from free compounds of the soil phosphorus.

The content of free phosphorus determined by the pot method labeled soil phosphates with radioactive phosphorus (P^{32}) was higher than the content of free phosphorus determined chemically (see Table 1). These divergencies can be explained by the fact that in the preparation of acid extracts a secondary adsorption of phosphorus by the soil takes place, so that chemical methods yield reduced values of free phosphorus.

We determined the secondary adsorption of phosphates in different extracts from the sod-podzolic soil used in the pot experiment. For this purpose we added a radioactive phosphorus isotope in the form of a $Na_2HP^{32}O_4$ solution possessing substantial activity and an insignificant content of P_2O_5 (1 mg of P_2O_5 per kg of soil) to the solutions with which the free phosphorus compounds were extracted from the soil. The value of the secondary adsorption of phosphates was determined from the difference between the activity of the original solution and the activity of the filtrate obtained after interaction of the solution with the soil. Table 3 presents the results of the determination of secondary adsorption of phosphates in various extracts.

The amounts of available phosphorus in the soil determined by the pot method and of soil phosphorus determined by the methods of Chirikov and Kirsanov, taking into account secondary adsorption, were fairly close to each other (6.8 mg of P_2O_5 compared with 9 mg and 9.2 mg of P_2O_5 per 100 g of soil, see Tables 2 and 3). The amount of available phosphorus in the soil determined by Egner's method turned out to be smaller in comparison with the results of the pot method (2.8 mg of P_2O_5 as compared to 6.8 mg of P_2O_5 per 100 g of soil).

From the data obtained in the pot method it follows that regardless of whether phosphate fertilizers were applied or whether the soil was limed, the quantity of available phosphates in the soil under the conditions of the experiment remained constant,[1] and only the percent of assimilation of available soil phosphates changed in different treatments of the experiment. This was apparently due to the fact that in our two months of experimentation there was no strong ameliorating effect on the soil that would have resulted in a sufficiently sharp change in the content of available phosphates in the soil. With local application of superphosphate and $CaCO_3$ to 100-gram layers of the soil, the effect of the latter on the properties of the rest of the soil in the layer (2.9 kg) could be only weak. Liming all the soil in the vessel at the rate of half the value of hydrolytic acidity (i.e., 4.65 g of $CaCO_3$ per vessel) could evidently produce a noticeable effect on the amount of free phosphates only after a considerable time elapse.

The tracer phosphorus used to determine available phosphates in the soil was suggested by A. V. Sokolov. The literature describes other methods (6, 5) which make it possible to determine the amount of available phosphorus

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[1] After subtracting the amount of phosphorus applied to the soil in phosphate fertilizers.

Table 3

Determination of the secondary adsorption of phosphates in extracts from sod-podzolic soil, using P^{32}

Methods of determining available phosphates in soils	Activity of 2 ml solution, counts/min			% of secondary adsorption	Available phosphorus, mg of P_2O_5 per 100 g of soil	
	Original solution	Filtrate	Adsorbed		Without comp. of secondary adsorption	With comp. of secondary ads.
Chirikov's method (0.5 n CH_3COOH solution)	218± 5	28± 1	190	87	1.2	9.2
Kirsanov's method (0.2 n HCl)	1350±15	530±10	820	61	3.5	9.0
Egner's method (calcium lactate solution)	280± 5	152± 3	128	46	1.5	2.8

in the soil provided that water-soluble radioactive phosphate fertilizers are carefully mixed with all the soil in the vessel.

The methods of Larsen, Fried and Dean are founded on the assumption that the degree of uptake of available soil phosphates and of fertilizers phosphorus is identical, i. e., that the percentage of phosphorus uptake from the soil and fertilizers is the same. For instance, in variant VI (S + Pc *"uniformly") the uptake labeled superphosphate by plants constituted 6.1 mg of P_2O_5 per vessel, which with the application of 105 mg of P_2O_5 per vessel amounted to 5.8% (see Table 2). Hence 5.8% of the total amount of soil phosphate had to come from the soil. We can compute the supply of available phosphates in the soil on this assumption. Since 8.7 mg of the phosphorus taken from the soil comprised 5.8% of the total amount of soil phosphates, the total quantity of available phosphates was

$$A = \frac{8.7 \times 100}{5.8} =$$

150 mg of P_2O_5 per vessel.

For the same treatment the uptake of available soil phosphates as determined by Sokolov's method amounted to 4.2% of the total quantity of soil phosphorus (Table 2). Inasmuch as the percentage of uptake of soil phosphorus as determined by the Sokolov's method is lower than that determined by methods of Larsen or Fried and Dean, the figure for the amount of all available phosphates in the soil became higher, constituting 204 mg of P_2O_5 per vessel or 6.8 mg per 100 g of soil. The total amount of available phosphorus determined by the methods of Larsen or of Fried and Dean amounted to 150 mg of P_2O_5 per vessel or 5 mg P_2O_5 per 100 g of soil both for treatment VI when superphosphate alone was applied to the soil and for treatment VII in which, together with superphosphate, lime was applied at the rate of one-half the hydrolytic acidity.

In the experiments of Larsen and of Fried and Dean, the content of available phosphates in the soil was determined by the rate of phosphorus uptake from fertilizers, which were applied in amounts capable of affecting the assimilation of soil phosphates. However, in the method suggested by Sokolov this effect is eliminated because a tracer in the form of radioactive isotope P^{32} is introduced into the soil. This tracer contains an insignificant amount of phosphorus (not exceeding 1 mg of P_2O_5 per kg of soil). At the same time it must be pointed out that the amount of available phosphates in the soil as determined by the Sokolov's method is also relative because his basic idea on the identical degree of assimilation of labeled phosphates and of available soil phosphates is only an assumption. It can be argued that not all the radioactive phosphorus entered the compounds used by the plants; some of it might have entered compounds that did not play a part in phosphate assimilation under the conditions of our experiment. However, the amount of radioactive phosphorus that might have entered difficulty soluble phosphates is evidently insignificant because of their poor solubility. The distribution of the tracer is determined by the equilibrium between the soil solution and the solid phase of the soil. Phosphorus introduced in an insignificant quantity does not disturb this equilibrium.

CONCLUSIONS

1. When superphosphate and lime were applied simultaneously to soil with an acid

reaction, the yield of plants and their phosphorus content were increased. The coefficient of phosphorus uptake from the superphosphate rose from 17% (without liming) to 25% in treatment in which $CaCO_3$ was applied locally and from 6% to 14% when superphosphate and lime were mixed with all the soil in the vessel. The simultaneous application of ground rock phosphate and lime under the same conditions sharply decreased both the yield and the uptake of phosphorus by plants in comparison with the effect of rock phosphate without liming.

2. The total content of available phosphates in the soil remained constant in different treatments of the experiment, but during the growing period the plants assimilated different quantities of phosphorus under various conditions. When the soil was limed, which promoted the development of the plants, the percentages of available soil phosphates that they assimilated rose.

3. The amounts of available soil phosphates determined by the methods of Larsen, Fried and Dean, and Sokolov under the conditions of the experiment were fairly close to each other.

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DYNAMICS OF SOIL MOISTURE IN RELATION TO TOPOGRAPHY

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The Bashkir Republic occupies an extensive area in the southern taiga, the forested steppe, the steppe of the Southern Urals and areas to the east and west of the Urals. Natural conditions are extremely varied within this area. The relief is highly dissected. Over three-quarters of the cultivated land is on slopes of varying steepness and exposure.

The steppe and forested steppe of Bashkiria periodically suffers from extreme atmospheric and soil drought and from wind and water erosion. Thus, drought prevention by the use of many agrotechnical measures to insure maximum accumulation and retention of soil moisture is of exceptionally great practical importance. Successful implementation of these measures requires a thorough knowledge of the hydrologic conditions in an area, especially of the soil-water regime. Problems associated with the laws of soil moisture behavior and control are of scientific and practical importance and have been thoroughly investigated for individual natural zones. A great deal of factual data has been accumulated, enabling us to develop especially adapted agricultural methods for the different soil-climatic zones of the country. However, this research has been conducted for the most part without due consideration of topography. This aspect of soil moisture dynamics has not been studied in the Bashkir Cis-Urals area. The problem of getting high yields of agricultural crops also demands knowledge of the laws of distribution and the methods of soil moisture control on all elements of the terrain within an area.

This paper briefly summarizes results of research conducted by us to clarify the dynamics of soil moisture as related to individual terrain elements. We investigated snow distribution, soil freezing, spring melting of snow and thawing of the soil, soil absorption of melt water, etc.

Research was conducted in 1951-1953 on the grounds of the demonstration and experimental farm of the Bashkir Agricultural Institute. The farm is situated on the left margin of the forested steppe of the Bashkir Cis-Urals. Relief in this area is rolling to hilly with a rather widely developed network of ravines. The degree of dissection is 0.5-1.5 km per 1 km^2, depth of local erosional levels is 25-125 m, while the average slopes are 1-3°.

Data provided by the Ufim meteorological station show that the annual precipitation in this zone varies between 392 and 527 mm. Thirty percent of this precipitation falls in the form of snow. The mean annual temperature is +2.4°C. The prevailing winter winds are southeasterly; they exercise their strongest influence on snow accumulation on slopes with southerly, southeasterly and northerly exposures.

The research was conducted on the lower, middle and upper parts of convexo-concave slopes with southerly and northerly exposures in the watershed area. The soil cover of the surrounding area and slopes consists of leached clay loam chernozems underlain by loess-like carbonaceous clay loam.

Table 1 shows that the soils of the experimental areas differ from one another in humus content, thickness of genetic horizons, and depth of effervescence. These differences are associated primarily with differences in surface runoff of melt water and sheet erosion. Farther away from the watershed (where there is virtually no sheet erosion), the slope of the area increases and runoff and sheet erosion intensify. This increase continues to the middle part of the slope, the steepest part. On their lower slopes runoff and sheet erosion are replaced by accumulation. A decrease in the thickness of the humus horizon and the humus content is observed to the middle part of the slope, while an increase is again observed on the lower part.

The depth of effervescence also changes depending on the elements of the terrain. Effervescence is deepest in areas with a

Table 1

Characteristics of experimental plots

Elements considered	South slope			Watershed	North slope		
	Lower portion	Middle portion	Upper portion		Lower portion	Middle portion	Upper portion
Absolute elevation, meters	95-100			129	118-120		
Slope, degrees	1.0	5.0	2.5	0.0	0.0	2.5	1.5
Humus, in % of A plowed	15.21	11.79	12.20	13.47	12.99	10.87	11.02
Horizon A thickness, cm	78	39	47	56	93	50	52
Horizon B thickness, cm	76	59	74	94	73	80	90
Effervescence depth, cm	105	94	100	120	Not observed to depth of 150 cm		

pronounced surface runoff and less deep where the soil is saturated with water (south slope). It is least deep on the smoother areas where there is deep saturation (owing to the absence of runoff or a thicker snow accumulation).

PRECIPITATION DISTRIBUTION AND SOIL FREEZING IN RELATION TO TOPOGRAPHY

Summer precipitation falling evenly over a limited area will not cause unequal soil moistening on the individual elements of the terrain. The character of the topography in an area does, however, influence the distribution of winter precipitation. As a rule the greatest snow accumulation is on low-lying terrain, while the least is on high and exposed areas. The snow is easily blown from the latter. Snow is accumulated on some slopes and stripped from others, depending on their exposure.

Table 2 shows the change in the snow depth depending on exposure and the individual parts of convexo-concave slopes. The conditions for snow accumulation on a south slope subject to the strongest action of prevailing southeasterly winter winds are less favorable than on a north slope, and the snow on a south slope is considerably less deep. Conditions for snow accumulation on the upper part of the watershed are still poorer.

Snow accumulation also varies along the same slope because the wind action is different on different parts of the slope. Snow accumulation on a south slope increases from the watershed line to the foot of the slope and becomes very deep on the lower part of the slope. The opposite is true on a north slope.

As is well known, winter soil freezing depends on many factors. Some of these accelerate the process, while others retard it. Mosolov (2), Kachinskiy (1) and others point out that the most important of these factors is the snow cover -- how deep it is and when it is formed. On this basis we may assume that the uneven distribution of snow on different elements of the terrain will result in differences in the depth of soil freezing. This has been proven to be the case. Table 2 shows a clearly expressed relationship between the thickness of the snow cover and the depth of soil freezing. On a south slope the depth of soil freezing decreases away from the watershed line as the snow cover increases in depth. The opposite is true on the north slope. The deepest soil freezing occurs on the watershed and on the upper part of the south slope. The depth of freezing also varies depending on the year of observation. In 1952 the depth of freezing for individual terrain elements ranged from 41-80 cm while in 1953 it was considerably smaller, 68-80 cm. These annual differences depend on the nature of the winter.

A stable snow cover was formed in the first half of 1951-1952, but not until February in the 1952-1953 season. As a result, the warming action of the snow cover in 1952-1953 was less pronounced than in the preceding year. This also explains why the soil froze deeper in the winter of 1952-1953 than it did in 1951-1952.

SNOW MELTING AND SPRING THAWING OF THE SOIL

It is known that entry of winter precipitation into soil during the melting of snow depends chiefly on the character of the joint processes of snow melting and soil thawing. We conducted observations to establish the influence of the relief on these processes. These observations included the melting of the snow, the thawing of the soil and determination of the extent to which melt water entered into the soil. These data are given in Table 3.

The process of snow melting progresses very unevenly on individual terrain elements and on different exposures. For example, the first thawed patches of 1952 appeared on the south slope on April 14 and on the watershed on April 15, but not until April 16 on the north slope. Table 3 shows that the entire period of snow melting lasted for 6 days on the middle part of the south slope, for 7 days on the watershed, and for 11 days on the north slope. The snow melting process progressed similarly in 1953.

The unequal rate at which the snow disap-

Table 2

Snow distribution and freezing depth of soil on slopes of different exposure before the beginning of snow melting

Elements considered	South slope			Watershed	North slope		
	Lower portion	Middle portion	Upper portion		Lower portion	Middle portion	Upper portion
Data for 1952							
Snow thickness, cm	42	26		25	47	54	58
Amount of water, metric tons/ha	1012	600		626	1175	1350	1450
Soil freezing depth, cm	52	70		80	45	45	41
Data for 1953							
Depth of snow, cm	61	57	55.1	44	65.2	67.4	71
Amount of water, metric tons/ha	1561	1260	1212	950.4	1480	1570	1746
Soil freezing depth, cm	70	78	80	80	69	70	68

Table 3

Snow melting and soil thawing, depending on the character of the relief

Terrain elements and exposure	Slope	Depth of soil freezing, cm	Date of snow disappearance	Duration of snow melting, days	Date soil completely thawed
Data for 1952					
South slope	Lower portion	52	Sept. 18	9	Sept. 22
	Middle "	70	" 15	6	" 25
Watershed		80	" 16	7	" 26
North slope	Lower portion	45	" 19	11	" 17
	Middle "	45	" 19	11	" 17
	Upper "	41	" 19	11	" 17
Data for 1953					
South slope	Lower portion	70	Sept. 15	12	Sept. 15
	Middle "	78	" 13	10	" 16
	Upper "	80	" 13	10	" 21
Watershed		80	" 14	11	" 21
North slope	Lower portion	69	" 16	13	" 14
	Middle "	70	" 16	13	" 14
	Upper "	68	" 16	13	" 13

peared on different terrain elements is associated with the difference in snow depth and the exposure of the slopes on which the intensity of insulation depends. For example, during the period April 8-15, 1952, all the snow (26 cm deep) melted off the middle part of the south slope, it decreased by only 17-20 cm on the north slope and by 21 cm on the watershed. This difference in the rate of snow disappearance means that these soils are ready for cultivation at different times; this should be taken into consideration when adopting technical agricultural measures.

Table 3 shows that the thawing of the soil progresses at different rates on the two slopes. On the south slope and watershed the soil did not thaw completely until the fourth to tenth day after the snow had disappeared. On the north slope, however, the soil thawed 2 to 3 days before the snow disappeared.

The period required for the soil to thaw also varies on different parts of the slopes and in the limits of one exposure.

Our observations showed that the length of this period depends on the depth of soil freezing and the character of the thawing process. The soil thaws more rapidly and at an earlier date the less deep the soil is frozen, and vice versa. The complete thawing of the soil is retarded if the soil under the snow cover only thaws from the bottom upward. Soil thawing speeds up considerably when it simultaneously proceeds from the surface downward and from the bottom upward. This two-directional thawing of the soil took place on the north slope during both years of observation. This, jointly with less deep freezing, resulted in a rapid thawing of the soil on this slope. This two-directional thawing of the soil under the snow was observed on the south slope and on the watershed in 1953. As a result, the soil had thawed 37-44 cm from the top by the time the snow had melted. It had completely thawed considerably more rapidly than in 1952.

It is generally believed (1, 3 and others) that thawing of the soil from the surface downward does not begin until the snow disappears, and that before this, it occurs only from the bottom upward. This is evidently the case in certain regions. In our research area, however, the soil thawed from the surface under the snow when the soil was frozen heterogeneously (which was evident when it was excavated to determine freezing depth). It is considerably easier to split heterogeneously frozen soil into blocks and lumps when dug than is the solidly frozen soil. It is probable that the density of soil freezing is influenced by the moisture in the fall, the severity of the winter, the depth of the snow, the exposure of the slope, etc.

In our two years of observations the principal factor causing a less solid freezing of the soil on the north slope (and also on the south slope in 1953) should be regarded as the deeper snow accumulation on those areas. A deep snow cover is the best protection for the soil against the cold winter, extraordinary cooling and sharp temperature changes. Under these conditions the rising water vapor is evidently weakened, as is the condensation of moisture in the upper layers of the soil. The larger pores between the clods of cultivated soil remain open, and this creates heterogeneous freezing of the soil. Soil thawing is accelerated owing to the downward penetration of warm air and its accumulation under the snow. An additional factor of great significance for the north slope is the protection of the watershed from the action of cold winter winds on the soil of the leeward slope.

Our data show that the state of the soil itself is also an influence on the density of freezing. In 1953, on one of the areas on the south slope, the thawing of the soil under the snow was not observed and the soil was more solidly frozen. This slope differed from the experimental slope only by the absence of fall plowing. In Bashkiria, therefore, the fall cultivation of the soil, together with other measures, should be of great importance in preventing the soil from freezing solid.

ENTRY OF MELT WATER INTO SOIL

The differences in the snow melting and soil thawing processes for different elements of the terrain results in a nonuniform entry of melt water into soil. This is illustrated in Table 4 (the quantitative entry of melt water was determined from the difference in spring and autumn soil moisture at a depth of 0-150 cm and from the moisture storage in the snow cover before the snow thaw).

Table 4 shows that the entry of winter precipitation into soil is very uneven on the two slopes and on individual portions of slopes.

During the period of observation minimum entry of melt water into soil was observed on the south slope; the soil there remained frozen until the snow had disappeared. Part of the winter precipitation was therefore lost in the surface runoff of melt water. The amount of runoff increases with an increase in slope. The minimum water entry is therefore found in a soil on the steeper middle part of the slope (in 1952 only 32% of the melt water entered the soil while 78.8% entered on the level watershed). The maximum entry of melt water occurred on the north slope (68-88% in 1952 and 81-100% in 1953); this was facilitated by the earlier thawing of the soil and the

Table 4

Entry of winter precipitation into soil on individual terrain elements

Terrain element and exposure	Slope	Water entry in:			
		1952		1953	
		Metric t/ha	% of winter storage	Metric t/ha	% of winter storage
Southern slope	Lower portion	671.0	57.7	1302.0	83.3
	Middle "	240.0	32.0	799.8	63.5
	Upper "			857.0	70.7
Watershed		604.0	78.8	757.0	79.7
Northern slope	Lower portion	1168.0	88.1	1665.4	100.0
	Middle "	1024.0	68.2	1234.6	80.8
	Upper "	1082.0	69.6		

greater duration of the snow melting process.

DYNAMICS OF SOIL MOISTURE

Inasmuch as the factors determining the entry of melt water into soil vary in intensity on different elements of the terrain, soil moisture cannot be identical at these points as shown in Table 5.

Observations of moisture dynamics in a fallow field were made over a period of three years. Data on moisture are given here only for the year 1951. For the other two years only the mean weighted indices for the five determinations made during the growing season are given.

Table 5 shows that the soil moisture regime within the boundaries of a limited area is quite variable. The maximum moisture is found on the north slope, where more melt water has entered into soil and the evaporation process is slower. Soil moisture also changes noticeably along the length of the slope. Away from the watershed it decreases with an increase in slope. There is again a considerable increase on the lower part of the slope. These moisture dynamics, resulting from nonuniform entry of spring water into soil, are persistent throughout the growing season.

The data in this table show that dessication of the soil occurs during the course of the year. This is because precipitation during this period cannot maintain the spring supply of soil moisture. A total of 178.1 mm of

Table 5

Dynamics of available moisture in Metric Tons/Hectare
in 0-100 cm soil layer (1951)

Date determined	South slope			Water-shed	North slope	
	Lower portion	Middle portion	Upper portion		Lower portion	Middle portion
April 22	1608	1424	1449	1806	2051	1442
May 15	1414	1226	1250	1578	1685	1295
June 7	1814	1367	1550	1906	2291	1457
July 3	1346	1054	1367	1535	1909	1145
August 10	1129	421	1021	1199	1537	774
Average contents for the growing season						
1951	1462	1098	1327	1604	1894	1222
1952	1514	1157	1406	1835	1878	1396
1953	2094	1545	1365	1651	2087	1314
For the 3 years	1690	1266	1365	1697	1957	1311

recipitation fell in the period from April 22 to ugust 10, 1951. This figure is broken down s follows: April 22-May 15 -- 23.3 mm; lay 15-June 7 -- 65 mm; June 7-July 3 -- 5.8 mm; July 3-August 10 -- 73 mm. Despite is, the supply of soil moisture decreased in ome areas during this same period, becoming everal times less than in the spring.

This difference in the dynamics of moisture n the individual parts of the terrain is due to e different intensity of evaporation on the ifferent parts of the slopes and to slope expos- re. For example, the precipitation falling etween May 15 and June 7, 1951 (at the rate f 650 metric tons/ha) increased the soil oisture on the lower part of the north slope y 606 metric tons/ha. The increase on the outh slope was 400 metric tons/ha. However, uring the period June 7-July 3 the loss of oisture in these areas was 382 and 468 me- ic tons/ha, respectively.

A similar phenomenon is also observed on e individual parts of a single slope, and this creases still more the difference in soil oisture in these areas by the end of the sum- er.

CONCLUSIONS

1. The local topography of an area is one the fundamental factors in the redistribution winter precipitation on the earth's surface.

When there are southeasterly winter winds e deepest accumulation of snow occurs on e north slope; considerably less amount ccumulates on the south slope. The least ccumulation of snow is found on the exposed atershed.

2. The depth of soil freezing also varies in tremely broad limits as the result of the neven distribution of snow on different terrain ements. As a rule, the deepest soil freezing ccurs on the watershed, it is somewhat less eep on the south slope and least deep on the orth slope.

3. The uneven accumulation of snow and the nuniform depth of soil freezing resulting om differences in exposure and terrain ele- ents create different conditions for snow elting and soil thawing. The deeper the soil eezes, the longer it will take to thaw in the pring. As a rule, the soil thaws on the north ope first, then on the south slope, and last n the watershed.

4. The different rates for snow melting and oil thawing on different terrain elements esults in an unequal utilization of winter pre- pitation by the soil. The earlier the soil thaws, the better entry of melt water into soil. In the years of observation on the north slope, where the soil thawed earlier than the snow disappeared, it made use of 68-100% of the melt water, versus 32-83% on the south slope.

The poorest conditions for entry of melt water into soil along the length of the slope develop in the middle part of the south slope. The soil remains frozen on the south slope until the snow disappears and a considerable part of the spring water is lost in the form of surface runoff.

5. Owing to this complex of factors the intake of spring moisture in the soil is extremely uneven on the individual parts of the terrain. As a rule, the north slope has the maximum supply of spring moisture. On the slopes themselves the maximum is found on the lower parts. A lesser supply of moisture is present in the soils of the upper parts of the slopes, and the very least -- in the soils of the middle parts of the slopes.

6. Some of the most important measures for moisture conservation are the protection of the soil from deep and solid winter freezing, prolongation of the snow-melting period and acceleration of spring thawing of the soil on irregular parts of the terrain. This should be accompanied by the detention of melt water by mechanical structures.

Such measures should include deep autumn cultivation, early snow retention, and other methods for warming the soil. Local topographic peculiarities should be taken into account. These measures should be taken particularly on the slopes (especially on the windward slopes), most of all where they are steep.

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DISCUSSION

THE STATUS AND DEVELOPMENT OF CLASSIFICATION PROBLEMS IN SOIL SCIENCE[1]

YE. N. IVANOVA AND N. N. ROZOV

At the present-day level of development in Soviet and world soil science the proper solution of the problem of soil classification is of great importance.

A unified soil classification, properly reflecting soil properties and fertility, is essential for large-scale soils mapping. It is also needed for the site index of soils, planning of technical, agricultural and reclamation measures, the computation of land areas and the interchange of agricultural experience within the Soviet Union and throughout the world.

A unified soil classification is also necessary for the successful development of other branches of soil science and a number of marginal disciplines. The problem of soil classification is the most important problem scheduled for consideration at the forthcoming Seventh International Congress of Soil Scientists.

An analysis of the overall development of the classification problem in soil science cannot be made without a parallel study of Soviet and foreign work on this problem.

Soil science, as a science, came into being more than a century ago. Since then much energy and labor has been expended on the stu of the morphological and physicochemical properties of soils. An immense amount of factual data has been accumulated in this field. A brilliant key to the generalization of these data has been provided by Dokuchayev's genetic concept, based on the idea of soil development in interaction with the surrounding environment. Thus two approaches to the various problems of soil science have been developed -- the morphological-physicochemical approach and the genetic approach. These do not contradict one another but instead are, so to speak, diffe ent stages in our knowledge. However, in solving the soil classification problem the only correct approach for purposes of generalization is the genetic approach.

In a recent review I. P. Gerasimov and Ye. N. Ivanova distinguish three main schools in the development of the classification problem in world soil science: Soviet, Western Europea and American. The schools differ in respect t their methods of morphological-physicochemical study of soils and in the depth and breadth of their genetic approach to the problem. Inasmuch as the task of establishing a unified world soil classification is a matter of the greatest importance, a deep scientific analysis of these schools and their gradual unification are becoming inevitable.

Let's briefly indicate the principal features of these schools.

The Soviet school is based on the simultaneous study of soil properties and processes of soil formation, and uses Dokuchayev's method of comparative geographical analysis. This approach makes broad genetic generalizations possible when solving the classification problem as a whole. It also permits an understanding of the genesis of individual groups, subgroup, genera and species of soils.

The Western European school as shown by

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[1] Report of the First Delegates' Congress of the All-Union Society of Soil Scientists. Participating in the preparation of this report were the Chairman of the Joint Committee on Nomenclature, Taxonomy and Soil Classification, Academician I. V. Tyurin, and the following committee members: Academician I. P. Gerasimov; V. A. Kovda, Corresponding Member, Academy of Sciences, USSR; Ye. N. Ivanova; N. N. Rozov.

Data received from a number of branches and divisions of the All-Union Society of Soil Scientists were used when preparing this report.

e papers and reports presented at the Sixth ernational Soil Congress and other published orks, engages in a profound study of individual il properties and the genesis of individual soil oups. We feel that the general classification ans developed by scholars of this school are cking in the necessary breadth and do not ways consider the influence of biological and imatic factors sufficiently. Problems of il evolution are usually regarded from a ngle aspect (chiefly from the parent material the soil or from a hydromorphous soil to automorphous soil) independently of the erall evolution of zonal landscapes.

The American school has its own peculiari- s in dealing with soil classification. It is aracterized by a long-existing break between e "great soil groups," genetic in nature, and emical-morphological series and American il types.

These special characteristics, however, do t exhaust the peculiarities of each of these hools. Therefore a careful study of foreign rk on the problems of soil classification is r most important task.

The past decade (1947-1957) has witnessed e intensive development of soil research in e USSR. In this period large-scale soil sur- ys have been made over an immense area -- ore than 100 million hectares. Numerous edium-scale soil maps of republics, oblasts d rayons and of large-scale reclamation and provement projects have covered an area about 300 million hectares. Abundant data ve been collected relative to the genesis of orly known soils of the dry subtropics, serts, forested regions of temperate mon- on climate, taiga-permafrost regions and ndra. These data have permitted us to con- der the delineation of several new soil groups d the subdivision of several "old" groups. ork on a geographical basis has also devel- ed in the USSR on the study of soil organic atter, the biological cycle of substances, the il moisture regime, and the composition of condary soil minerals. These matters are great importance in the solution of the clas- fication problem.

All the foregoing soil data have been gen- alized for classification purposes at two ales: regional and All-Union. Regional il classification work has been carried on a number of republics and oblasts. It has sulted, in particular, in the preparation of ographical soils reports for the individual publics and other territories. In many cases e regional classification plans have proven to related inadequately to one another and to e All-Union plan in respect to taxonomy and menclature.

To assess the current status of regional classification work, we assembled regional systematic lists of soils and analyzed the reports dealing with soil classification problems that had been presented at the First Delegates' Congress of Soil Scientists.

This analysis of the latest data on the problems of taxonomy and soil classification was made separately for soils of the nonchernozem zone, for steppe soils and for desert and mountain soils.

Data for the classification of soils in the nonchernozem zone were presented in reports and papers delivered by: P. P. Garmus (Lithuanian SSR), A. I. Lillem (Estonian SSR), I. V. Zaboyeva, S. V. Belyayev and D. M. Rubtsov (Komi ASSR), K. A. Krumin'sh and K. Brivkaln (Latvian SSR), N. Ya. Korotayev (Perm Oblast), V. N. Smirnov (Mari ASSR), N. N. Sered (Ukranian SSR), N. N. Pitulko (Ukrainian SSR), M. A. Toyko and A. M. Volodin (Karelian ASSR), S. A. Zolotarev (Ukranian SSR), M. F. Kurochkin (Tatar ASSR), S. A. Kolyago (Tomsk Oblast), N. V. Kazantsev (Krasnoyarsk Kray), V. M. Prudnikov (Omsk Oblast), M. M. Merinov and M. S. Shigayev (Bashkir ASSR), and S. N. Taychinov (Bashkir ASSR).

The following soil groups are delineated in most reports: 1) podzolic, 2) podzolic-bog, 3) sod-carbonate, 4) sod-gley, 5) bog (or a group of bog, 6) grey forest and 7) grey forest gley.

What constitutes a soil group differs from system to system. For example, the reports for Omsk Oblast and the report submitted by M. M. Merinov and M. S. Shigayev list sod-podzolic soils separately from podzolic soils; they are given as a special group. N. V. Kazantsev's system has secondary podzolic soils as a special group. In all other reports interfluvial podzolic soils are examined as a unit.

Great differences are manifest in the interpretation of the systematic position of podzolic-bog soils. The classification for Omsk Oblast includes podzolic-bog soils in the podzolic group as a subgroup. The soil classification for the Latvian SSR lists podzolic-bog soils, together with sod-gley soils, as constituents of the type "bog-mineral soils."

On the other hand, the soil classification for Krasnoyarsk Kray subordinates podzolic-bog soils to bog soils. The majority of classifications presented, however, list podzolic-bog soils as an independent soil group.

The grey forest soil group also differs from report to report. S. A. Zolotarev's report includes the brown forest soils of the Carpathians and the Far East under the grey forest soils. In the classifications presented by N. Ya.

Korotayev and M. M. Merinov and M. S. Shigayev the grey forest soils also include podzolized and leached chernozems, thereby breaking up the integrity of the chernozem group.

In the other communications the grey forest soils are regarded as an independent group, broken down into these subgroups: light-grey, grey and dark-grey forest soils. In a number of cases the terms "brown" and "cinnamon" have been incorrectly applied to grey forest soils without any special explanation.

Grey forest gley soils have been set off as an independent soil group in the systematic lists for Bashkiria and Tomsk Oblast.

There is much variation in the classification of bog soils. Four groups of bog soils are distinguished for KomiASSR: bog tundra-permafrost, peat-bog soils of upland, humus-bog soils of low land, and alluvial-bog soils of flood plains. Only one bog soil group is listed for the Estonian SSR, Mari ASSR, and Voronezh, Omsk and Tomsk Oblasts. There are bog soil subgroups for upland, lowland and transitional areas.

In all the papers presented, flood plain soils are divided by following similar principles -- soil groups are distinguished by stages of development and by the duration of inundation. The systematic position of these groups, however, is determined differently by the different authors.

Data on the systematization of steppe soils are given in reports and communications presented by M. M. Merinov and M. S. Shigayev, S. N. Taychinov, I. P. Lovetskiy, V. M. Prudnikova, N. V. Kazantsev, Ye. S. Blazhniy, B. V. Nadezhdin, S. A. Kolyago, M. F. Kurochkin and N. Ya. Korotayev.

The following soil groups are usually distinguished in the steppe zone: chernozems, meadow-chernozem, chestnut, meadow-chestnut, meadow-bog, solonchak, solonetz and solodi.

Significant deviations from this arrangement are found principally in the classifications for Omsk Oblast and Krasnoyarsk Kray and in the report presented by Merinov and Shigayev. In the systematization for Omsk Oblast carbonate chernozems are distinguished as an independent soil group while solonetzic chernozems and solodized chernozems are under special solonetz and solodi soil groups. In the classification for Krasnoyarsk Kray this is supplemented by a special soil group -- "puffy" chernozems. This classification therefore varies radically from that in many other reports where the chernozem group is regarded as a unit.

B. V. Nadezhdin has proposed the separation of a special province of chernozems along the Angara River. Such a separation is possible, but we should point out here that he gives no explanation as to why the Angara soil province is characterized by shallow solonetzic chernozems. Neither does the author demonstrate the solonetzic character of these soils (he gives no data concerning measurements of absorbed sodium).

Almost all the taxonomic lists have the chernozems divided into species depending on their humus characteristics (the humus content and the thickness of the humus horizon) and on the salt profile (in the broad meaning of the term). It should be noted, however, that not all systems use one and the same gradations for thickness of the chernozems; this makes it difficult to match soil names from region to region.

Chestnut soils were discussed in three papers. For Krasnodarsk Kray (N. V. Kazantsev) and the Kirgiz SSR (G. I. Roychenko), chestnut soils are divided into three subgroups (by subzones): dark-chestnut, chestnut and light-chestnut soils. The following are distinguished in a report dealing with Krasnodarsk Kray (Ye. S. Blazhniy): Carbonate deep-chestnut and shallow-solonetzic chestnut soils. This reflects the peculiar environmental features of the Cis-Caucasian chestnut soils.

Meadow-chernozem and meadow-chestnut soils are treated as special soil groups in reports and papers presented by S. A. Kolyago, S. N. Taychinov, N. V. Kazantsev, Ye. S. Blazhniy and Ye. I. Roychenko. Meadow-chernozem soils are included under the chernozem group in the classification for Voronezh Oblast. In Perm Oblast they are classified under the so-called forested steppe soil group while for Omsk Oblast they are evidently listed under the solonetzic and solodized groups.

S. N. Taychinov and V. M. Prudnikova give meadow soils as an independent soil group. S. A. Kolyago and S. N. Taychinov distinguish meadow-bogs as an independent soil group.

In an overwhelming majority of cases solonetz, solonchaks and solods are regarded as independent soil groups and are divided into steppe and meadow categories.

The classification of desert and mountain soils was the subject of only a few reports: B. V. Gorbunov and N. V. Kimberg (Uzbek SSR), G. A. Aliyev (Azerbaydzhan SSR), G. I. Roychenko (Kirgiz SSR), A. P. Lavrov (Turkmen SSR) and V. V. Yegorov (V. V. Dokuchayev Soil Institute, Academy of Sciences USSR).

These papers distinguish the following

esert soil groups: grey-brown, light-brown f Central Tien Shan, desert-meadow, desert-og, solonchaks, solonetz and takyrs. The llowing were given for soils of semidesert othills and low mountains: sierozems, siero-em-meadow, and sierozem-solonetz.

The grey-browns are considered a zonal oils of deserts (Gorbunov, Kimberg).

Takyrs in some cases are set off as an inde-endent soil group (Lavrov), while in other ases takyr and meadow-takyr are combined to a single group called takyr soils. This is stage in soil development from flood plain eadow to zonal desert (Gorbunov, Kimberg, egorov).

In the desert-meadow and desert-bog soils e included the flood plain-meadow and bog oils of the desert zone. The delimitation of special group of sandy desert soils is also oposed.

The soils of the semidesert-foothills zone e classified in various ways. In Kirgizia n environmental division is used as the basis r a breakdown into northern sierozems emirech'ye) and southern sierozems. The erozems of Uzbekistan are primarily divided to light, ordinary and dark. We feel that is necessary to integrate these two approach-, possibly by forming one taxonomic class.

There is still a great deal that is not clear d contradictory regarding systematization mountain soils. This is due to the complex-y of vertical zonality and the limited study at has been devoted to mountain soils. In entral Asia, above the belt of mountain siero-ems, in some cases there are brown forest ountain soils and cinnamon-brown soils. In her cases there are mountain chestnut soils d chernozems. The soils of the Tien Shan r, walnut and juniper forests are still in-dequately described, while the peculiarities the light-brown soils of the Central Tien an are not yet fully understood. Insufficient udy has been devoted to the complex series high mountain meadow, meadow-steppe, d desert soils. More study has been devoted the soils of the Caucasus, but here also oblems arise relative to the delimitation of ountain chernozems and chestnut soils on the e hand and cinnamon-brown and grey-cinna-on-brown soils on the other.

A number of reports devote serious atten-on to arable soils that have been modified as result of agricultural utilization. This cir-umstance is very gratifying but there is no eed for unanimity of opinion on this susbject.

The classifications for the Komi ASSR, Omsk blast and the Latvian SSR and the works of B. Gorbunov, N. V. Kimberg, G. N. Roychenko and A. N. Rozanov distinguish cultivated varieties of different soil groups for Central Asia. They thereby recognize that group characteristics are preserved in cultivated soils. V. N. Smirnov and M. A. Orlov hold a somewhat different point of view. They note the influence on cultivated soils of only a few overall zonal conditions. We feel that the first viewpoint is the more correct, considered either from the matter of genesis or the matter of productivity.

In summarizing the results of our study of regional taxonomy, we should note that despite the existing diversity of viewpoints the majority of scholars have nevertheless adhered to the system and nomenclature of the State soil map. They have usually introduced only small deviations from that system. It is interesting to note that the classifications are the closest to the All-Union system in all those cases when the authors are dealing with large areas and a great variety of soils. On the other hand, when the variety of soils is limited the authors tend to offer various original classifications. Such classifications can scarcely pretend to any general significance.

The following question spontaneously comes to mind after making this review: how is it possible to do away with the existing and often abstruse discrepancies in classification and nomenclature?

Two approaches can be suggested here: 1) the establishment of wider contacts between workers in various geographical regions and 2) intensification and expansion of generalization work for the classification of soils at the All-Union scale.

During the past decade considerable generalization work has been done in the field of small-scale soils mapping and classification. Those works of a collective character, having All-Union significance should be mentioned:

1) Considerable work on the compilation of the State soil map. The personnel on this project has now been increased to 100 persons.

2) The work of the All-Union Conferences of 1947, 1950 and 1956. These devoted a great deal of attention to the classification problem.

3) Discussions relative to classification problems published in the journal Pochvovedeniye. About 20 Soviet and foreign scholars have expressed their views in these articles.

4) Finally, work done by the Joint Committee on Soil Nomenclature, Taxonomy and Classification, established by resolution of the All-Union Conference of Soil Scientists in 1956. The Committee has held two plenary meetings and a number of preliminary sessions

of the working group during the last two years. The Committee presently has more than 40 members.

A number of important aspects of the classification problem have been solved as a result of these activities. The Joint Committee has worked out the definition of soil group as the basic unit for use in soil classification; the taxonomic units below soil group have been established and provided with definitions; the fundamental soil groups in the USSR have been delimited, together with their main subdivisions, on the published sheets of the State soil map. The Joint Committee is planning a unified soil classification and nomenclature for its publications. This will show four main soil groups for the USSR, oriented principally towards agriculture: podzols, grey forest soils, chernozems and chestnuts.

For the present we still do not have a unified classification above the soil group that is satisfactory for all purposes. However the principles for devising one have already been planned.

The classification should be drawn up using as a point of departure both the evolution of the individual soils and soil formation as a whole. The classification should consider the soil moisture regime and the phenomenon of hydromorphism. The development of individual soils must be studied in relation to changes in relief and the volution of bioclimatic conditions. Therefore all soil groups, both zonal and intrazonal, should to some degree carry the "imprint" of the zone.

These principles were accepted by a majority of those participating in the discussion and by a majority of the members of the Joint Committee. Several other viewpoints were also expressed. The definitions of soil group and the other taxonomic units were published in the journal Pochvovedeniye, No. 8. 1957.

As a point of departure for the development of a unified soil classification the Joint Committee had available the unified general listing of the soils used for the State soil map of the USSR. This had been worked out on principles approved by the All-Union Conference in 1950. Also available were regional classification schemes differing from it in peculiarities of nomenclature and structure.

As a result of prolonged deliberations at the two plenary sessions of the Committee, it was decided to bring the proposed classifications shown in Tables 1 and 2 to the attention of the Congress. These classifications reflect the opinion of a majority of the Committee members, but still do not do away with a number of discrepancies (especially in the case of the classification shown in Table 2).

Let's make several brief clarifications of these classifications.

1. The classification tables show soil groups, subgroups and the principal genera.

2. When delimiting soil subgroups of podzols, chernozems and chestnut "environmental" peculiarities having very great significance in agriculture were taken into consideration in addition to subzonal peculiarities. This was in accordance with the wishes expressed at the First Plenary Session of the Committee.

Among such "environmental" subgroups the podzolic soils include "humus-podzolic soils," the chernozems include the unusual "Black Sea Area" and "Eastern Asiatic" subgroups, while the chestnut soils include "Cis-Caucasian" and Central Asiatic" subgroups. All these subgroups were distinguished on the basis of presently available data for both the USSR and for adjoining countries. We should not overlook the singularity and great agronomic differences in the soils of different environments and this should be reflected in our classification systems.

3. In view of the difficulty of developing a new soils nomenclature, the tables give temporary working names. They are given in parentheses.

4. The tables include all the principal comments made at the plenary sessions of the Joint Committee; these are used to achieve unity of opinion.

Thus (as a result of comments by a number of Committee members), surface gley and gley-subsurface soils are included under semihydromorphous soils. These are of great significance in respect to genesis and reclamation. The Committee also entertained a proposal made by K. P. Gorshenin relative to the breaking up of Dokuchayev's "traditional" podzolic and chernozem groups. Two groups are proposed to replace podzols: podzolic (in the narrow meaning of the word) and sod-podzolic. Two groups are also proposed to replace chernozems: chernozem-forested steppe soils and chernozem-steppe soils.

The question of a future work program on the classification problem is of great importance. Therefore the Joint Committee proposed the following program at its last Plenary Session:

1) Completion of a unified systematization of the soils of the taiga-forest and chernozem-steppe zones; 2) development of a unified systematization of the desert, salinized and subtropical USSR soils which lie adjacent to neighboring countries; 3) development of a systematization of arable soils which have been modified under agricultural use; 4)

Table 1

Soil Classification of the Taiga-Forest Zone of the USSR (Excluding Eastern Regions) (Following Data Provided by the Joint Committee on Soil Nomenclature, Taxonomy and Classification)

Podzolic soils

Subgroups:	Principal genera:
Gley-podzolic	Illuvial-humic
Podzolic	Illuvial-iron
Sod-podzolic	Common
Humic-podzolic	Residual-carbonate
	Secondary-podzolic (with second humus horizons)

Podzolic-bog soils

Subgroups:		Principal genera:
Gley-peat	(upper horizons)	Iron-impregnated (mineralized) (surface horizons)
Gley-sod	(upper horizons)	
Gley-peat	(lower horizons)	Illuvial-humic
Gley-sod	(lower horizons)	
Gley-peat	(upper horizons)	Typical
Gley-humic	(upper horizons)	
Gley-peat	(lower horizons)	Residual-carbonate
Gley-humic	(lower horizons)	

Upland bog soils

Subgroups:	Principal genera:
Peat-gley	Typical
Peat (in lower horizons)	

Lowland bog soils

Subgroups:	Principal genera:
Peat-gley	Typical
Peat-humic	Mineralized
Humic-gley	
Peat (in lower horizons)	
Peat-humic (in lower horizons	
Humic (in lower horizons)	

Sod (Taiga forest) soils

Subgroups:	Principal genera:
Typical	Carbonate
Leached	Residual-carbonate
Podzolized	Noncarbonate

Sod-gley (Taiga forest) soils

Subgroups:		Principal genera:
Gley-sod	(upper horizons)	Carbonaceous
Gley-sod	(lower horizons)	Residual-carbonate
Gley-sod	(upper horizons)	Saturated
Gley-sod	(lower horizons)	Podzolized
Humic-sod	(lower horizons)	

Grey forest soils

Subgroups:	Principal genera:
Light grey	Residual-carbonate
Grey	Cinnamon-brown-grey (brown, etc.)
Dark grey	Residual-podzolic
	Typical
	Secondary-podzolized

Grey forest gley soils

Subgroups:		Principal genera:
Gley	(upper horizons)	Residual-carbonate
Gley	(lower horizons)	Typical
Gley	(upper horizons)	Solonetzic (lower horizons)
Gley	(lower horizons)	Solodized

Table 2

Soil Classification of the Chernozem-Steppe Zone of the USSR (Using Data Submitted for Discussion by the Joint Committee on Soil Nomenclature, Taxonomy and Classification)

Chernozems		Meadow-Chernozem soils		Meadow soils	
Subgroups:	Principal genera:	Subgroups:	Principal genera:	Subgroups:	Principal genera:
Podzolized	Residual-podzolic	Meadow-chernozem (upper horizons)	Podzolized	Meadow "intermittently moist" (gley in lower horizons)	Deeply leached
Leached	Residual-solodized				
Leached "Black Sea Area" (highly mycelium-carbonate)	Noncarbonate	Meadow-chernozem (lower horizons)	Leached	Meadow "permanently moist" (gley in upper horizons)	Leached
"Weakly leached Black Sea Area" (mycelium-carbonate)	Normal (in respect to subgroups)	Permafrost-meadow-chernozem	Typical		
Typical	Residual-carbonate	Meadow-chernozem (upper horizons)	Carbonate		Typical
Common	Residual-solonetzic	Meadow-chernozem (lower horizons)	Solodized		Carbonate
Common "eroded" (Eastern Asiatic)	Solonetzic		Solonetzic		Marly
Southern		Permafrost-meadow-chernozem	Solonchak-like		Solodized
Southern "eroded" (Eastern Asiatic)					Solonetzic
Carbonaceous "Black Sea Area" (highly mycelium-carbonate)					Solonchak-like
Chestnut-mycelium-carbonate					Solonchak

Chestnut soils		Meadow-chestnut soils		Meadow-swampy soils	
Subgroups:	Principal genera:	Subgroups:	Principal genera:	Subgroups:	Principal genera:
Dark chestnut	Non-carbonate	Surface meadow-chestnut	Deeply leached	Meadow-swampy humic soils	Typical
Dark chestnut mycelium-carbonate (Ciscaucasus)	"Normal" (according to subgroup) deep-carbonate	Soil material meadow-chestnut	Leached	Meadow-swampy clayey soils	Carbonate
		Surface meadow-chestnut	Typical		
Dark chestnut "leached" (East Asian)	Residual-carbonate solodized	Soil material meadow-chestnut	Carbonate		Marly
Chestnut			Solodized		Solodized
Chestnut "leached" (East Asian)	Residual-solonetzic		Solonetzic		Solonetzic
Light chestnut	Solonetzic		Solonchak-like		Solonchak-like

Notes: 1) provisional, working names of soils are given in quotation marks; 2) the term "Black Sea" combines the terms "Ciscaucasus," "Azov" and "Danube"; 3) the term mycelium-carbonate is intended to mean steppe soils with highly mobile carbonates; 4) "leached" designates steppe soils from which the easily soluble salts have been removed.

development of a unified analysis and nomenclature of the USSR soils, including their agricultural characteristics and ways of improving them; 5) reduction of local soil subdivisions and names to a unified All-Union nomenclature.

This program should be supplemented by extensive work associated with the participation of USSR soil scientists in development of a soil classification for Europe and Asia. This is in accordance with the international commitments of the All-Union Society of Soil Scientists to the VII International Congress of Soil Scientists.

It is necessary to reach an agreement relative to work procedures and organization. Despite the immense amount of data accumulated by soil science, many problems of soil genesis still remain unsolved and subject to dispute. In solving the classification problem we therefore cannot limit ourselves to the collection of existing data, but must carry on new genetic research in accordance with a fixed plan. The formulation of a program for this genetic research should be based on the unanswered questions noted during the solution of classification problems. Among these are problems of hydromorphism, processes of humus formation, the formation of soils of the "lessive" type, weathering, and many others. The basic lines for this work plan should probably be proposed by the Joint Committee.

We consider cooperation and teamwork to be the basic principle for the organization of work on the classification problem. This approach has justified itself in the solution of many problems. The principal instrument to be used in accomplishing this work should be All-Union conferences (including plenary sessions of the Joint Committee) for thorough debate and solution of common problems. These common decisions should be the basis for the development of the work of regional conferences to apply these general principles to local conditions, work out systematic lists of soils with appropriate site quality index and improvement, and lay the way for their use in practical work.

METHODS

ACIDITY CHANGES IN SANDY SOILS AS AFFECTED BY THE HILL METHOD OF APPLYING FERTILIZERS

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Collective farms and state farms often use the same amounts of mineral fertilizers for various crops regardless of local soil conditions. This not only reduces the efficiency of the fertilizers, but also causes low yields. We know (1, 2) that when mineral fertilizers are applied to soils that are not base saturated, acidification of the soil solution takes place -- the larger the amount of mineral fertilizer and the lower the buffering ability of the soil, the stronger the acidification effect. On chernozems and clay soils that possess higher buffering capacity, the application of fairly high amounts of mineral fertilizer does not acidify the soil solution as is the case with acid sod-podzolic soils, especially coarse-textured soils (sands and sandy loams).

At the Novozybkov Agricultural Experimental Station located in a zone of sands and sandy loams we have repeatedly observed a lower efficiency of mineral fertilizers on these soils in drier years. An especially sharp reduction in fertilizer efficiency occurred when the latter was placed together with seeds either in rows or hills. With this method of applying fertilizer the amount appears to be small, but the total per unit of area at the application sites is quite substantial.

It has been calculated (Table 1) that with the broadcast of one centner of fertilizer per hectare the whole amount is evenly distributed throughout the area without causing any noticeable increase in the concentration of salts in the soil solution (0.01%). In applying fertilizer to grain crops using the row method the same amount covers the only 2000 sq meters of a hectare, increasing the concentration of salts in the soil almost five-fold (about 0.05%): On the other hand, when the square-hill method of putting fertilizer directly into the holes is used, and the plant feeding area is 70 x 70 cm, the same amount of fertilizer covers only 205 m^2/ha and is capable of raising the salt concentration on sites by a minimum of about 0.5%, i.e., a fifty-fold increase.

It is quite evident that with placement application of fertilizer (using the row and, particularly, the hill method) comparatively small amounts of mineral fertilizers (of the order of 1 cntr/ha in terms of the area actually fertilized) come to about 50 cntr/ha in case of the square-hill method. Such high doses of fertilizers cannot help but affect the physicochemical properties of the soil and, above all, growth of the young seedlings. Unfortunately, those using fertilizers, and even agronomists, do not pay enough attention to this problem. One should especially guard against a routine approach to the placement application of mineral fertilizers on sandy soils with poor buffering properties.

In view of the foregoing considerations and the practical importance of this problem, we conducted laboratory and field tests to determine the effect of various mineral fertilizers and the amounts on the changes in properties in sandy soils. The tests were made concurrently with observation of corn shoots.[1]

The tests were conducted on two kinds of soils (on deep and shallow sands of the Novozybkov Agricultural Experimental Station) that are widely found in the southwestern part of Bryansk oblast, Belorussia, and in the Polesye Region of the Ukraine (Table 2).

We also ran brief field tests on small field plots with deep mellow sands to ascertain the effect of mineral fertilizers on the acidity of sandy soils when applied in the usual amounts with the hill method of planting. The usual

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[1] Ye. A. Pal'kova, a student of the Beloruss Agricultural Academy who was taking practical training at our station participated in this research.

Table 1

Amounts of fertilizer per unit of area with various application methods

Indices	Methods of fertilizer application		
	Broad-casting	Row 3x15 cm	Hill 70x70 cm
Nominal amount of fertilizers, cntr/ha	1.0	1.0	1.0
Actual fertilized area, m^2/ha	10000	2000	205
Actual amount of fertilizers at application sites per unit of area, cntr/ha	1.0	5.0	48.8
Conditional weight of soil in contact with fertilizers, metric tons/ha	1000	200	20.5
Salt concentration, % of soil weight	0.010	0.05	0.50

Note: The depth to which fertilizers were mixed with soil was taken as 7 cm, the area of the hill 10x10 = 100 cm^2, bulk density of the soil 1.4 g/cc.

Table 2

Chemical properties of the soils

Soil	pH of the salt extract	Hydrolytic acidity	Sum of adsorbed cations	Humus, %	Particles <0.01 mm in diameter, %
	Meq per 100 g of soil				
Weakly podzolic mellow sand	5.1-5.9	2.44	1.34	0.58	5.71
Weakly podzolic fine sand	4.9-5.4	1.61	3.27	0.96	7.72

forms of fertilizers were introduced in a layer 5 cm deep: ordinary superphosphate, ammonium nitrate, and potassium chloride.

The size of the field plot was 0.5 sq meters. Each kind of fertilizer under study was applied at the rate of 0.5 cntr/ha on the basis of coverage of an area of 70 x 70 cm with the square-hill method of planting. In other words, each hill received 2.5 g of fertilizer. Five and 10 days after fertilizer application samples of soil layers at 2 cm intervals were taken and water extracts prepared with a soil to solution ratio of 1:2.5. The titratable acidity, the pH value obtained colorimetrically, and the total concentration of water-soluble salts were determined in the extract.

The results and arrangement of this experiment are presented in Table 3.

The data show that within five days the placement application of 0.5 cntr/ha of superphosphate raised the titratable acidity of sandy soil in the water extract about 0.47 meq per 100 g of soil, at the site of application, i.e., more than ten times that of the control plot (the figures cannot be presented in this short article). At the same time the actual acidity increased from pH 6.0 to pH 5.4 and the concentration of salts rose from 0.01 to 0.26%. The addition of 0.5 cntr/ha of ammonium nitrate to the superphosphate increased the titratable acidity of the water extract to 1.79 meq, i.e., almost 60 times as high as that of the control, and at the same time raised the salt concentration to 0.57%. The application of complete mineral fertilizer, i.e., addition of potassium chloride (0.5 cntr/ha) to PN, raised the titratable acidity to 2.67 meq per 100 g of soil and the salt concentration to 1.33% at the sites where the fertilizers were applied.

Ten days after application of the fertilizers, when there was 17.8 mm of precipitation, the acidity and salt concentration decreased somewhat mostly because the fertilizers moved into the lower layers of the soil. They still remained at a fairly high level both in the case of superphosphate alone and in the cases of

Table 3

Effect of fertilizers on changes in acidity and concentration of salts in soil water extracts

Arrangement of the experiment	Depth, cm	Five days after fertilizer application			Ten days after fertilizer application		
		pH	Titratable acidity of the water extract, meq per 100 g of soil	Concentration of salts, %	pH	Acidity, meq per 100 g of soil	Concentration of salts, %
Superphosphate (0.5 cntr/ha)	0—2	5,8	0,03	0,01	6,0	0,01	0,03
	2—4	5,8	0,03	0,02	6,0	0,05	0,02
	4—6	5,4	0,47	0,26	5,8	0,53	0,27
	6—8	5,8	0,08	0,03	5,5	0,13	0,04
	8—10	5,8	0,04	0,02	5,5	0,06	0,03
Superphosphate (0.5 cntr/ha) plus ammonium nitrate (0.5 cntr/ha)	0—2	5,8	0,06	0,03	6,0	0,06	0,02
	2—4	5,6	0,56	0,15	6,0	0,14	0,02
	4—6	5,4	1,79	0,57	5,8	1,30	0,38
	6—8	5,6	1,52	0,40	5,6	1,90	0,40
	8—10	5,6	1,04	0,31	5,6	1,85	0,44
Superphosphate (0.5 cntr/ha) plus ammonium nitrate (0.5 cntr/ha) plus potassium chloride (0.5 cntr/ha)	0—2	5,6	0,56	0,15	6,0	0,08	0,03
	2—4	5,5	1,25	0,51	5,8	0,35	0,09
	4—6	5,2	2,67	1,33	5,2	2,10	0,96
	6—8	5,4	1,72	0,62	5,2	2,29	1,04
	8—10	5,4	0,78	0,23	5,3	2,26	0,86

Note: Comma represents decimal point.

the double and triple fertilizers. Thus, this pilot experiment demonstrated that the placement of mineral fertilizers markedly acidifies the soil where applied and that the resultant acidification remains for ten days or more, i. e., throughout the period of determination and appearance of shoots.

FIELD TESTS WITH CORN

Having in our possession the pilot experiment data, we conducted field tests on small plots to ascertain the effect of various fertilizers and combinations of fertilizers on corn germination when inserted together with the seeds directly into the hill seedbed. One-third of the plots hills with fertilizers were left unplanted to serve for observation of changes in soil acidity caused by fertilizers. Each plot contained twenty hills with seeds (five seeds per hill) and six hills with fertilizers only. Ten and 20 days after the application, soil samples were taken at a depth of 0 to 10 cm from the center of the hill with an auger 6 cm in diameter.

On the eighth day after the experiments were started, corn was vigorously germinating on the non-fertilized field plots and on the plots with superphosphate alone, whereas on the rest of the plots the corn was slow in germinating and defective. Twenty days after germination the plants were counted, and after 40 days the total amount of corn per plot was determined. The results together with the data of soil analysis are presented in Table 4.

The results of this experiment indicate that the application of superphosphate alone at the rate of 2 g per hole (which for 20.5 thousand holes amounts to 0.41 cntr/ha) reduced the number of corn plants by 17% as against the control. The addition of the same quantity of ammonium nitrate to the superphosphate reduces the number of plants to one-third. However, the application of a double amount of superphosphate and ammonium nitrate (4 g of each per hole) together with 2 g of potassium chloride (which adds up to about 2 cntr/ha of fertilizers) resulted in almost complete loss

Table 4

Effect of hill fertilization on corn germination and acidity of soil water extracts

Amounts of fertilizers, g per hill (seedbed)	Corn germination, % of the number of seeds planted	pH		Titratable acidity of water extract, meq per 100 g of soil		Concentration of salts %		Weight of single plant 40 days
		At germination	After 20 days	At germination	After 20 days	At germination	After 20 days	After germination
Control without fertilizer	70	5.8	6.0	0.03	0.03	0.02	0.02	10.7
Pc 2 g	53	5.3	5.5	0.24	0.18	0.19	0.17	14.7
Pc 2 g + Naa 2 g	23	5.2	5.4	0.51	0.41	0.21	0.22	15.9
Pc + Naa 2 g each + Kx 1 g	20	5.3	5.4	0.49	0.42	0.19	0.25	16.9
Pc + Naa 4 g each + Kx 2 g	13	5.1	5.3	0.50	0.39	0.39	0.30	29.0

Note: Pc - ordinary superphosphate; Naa - ammonium nitrate; Kx - potassium chloride.

of corn plants.

A comparison of the number of corn germinated in relation to various fertilizers with soil acidity indicates that the sharpest increase in actual and titratable acidity of the water extract taken from the soil at the site of application is caused by ammonium nitrate, a smaller increase by superphosphate; potassium chloride brings about a comparatively low acidification. Thus, the introduction of 2 g of superphosphate into a hole raises the titratable acidity from 0.03 to 0.24 meq, whereas the addition of 2 g of ammonium nitrate brings the acidity up to 0.51 meq per 100 g of soil at the time of germination, i. e., it increases the acidity, to 17 times that of the control. The supplemental introduction of 1 g of potassium chloride does not cause a further acidification at the site of application. The kind of effect on the soil acidity produced by individual fertilizers depends upon their total physiological and biological acidity.

The detrimental effect of mineral fertilizers on the percent germination of corn is also due to increased salt concentration in the soil solution; however, they raise salt concentration less than they do titratable acidity. It will further be noted that plants given increased amounts of fertilizers subsequently developed normally and yielded a better growth of organic mass per plant than the control plants (without fertilizers). Thus, the weight of a single plant, given a double dose of NPK, on the fortieth day after germination was 29.4 g, whereas the weight of a single plant in the control was only 10.7 g, although, the yield of all the plants on the plot was much higher. This indicates that acidification of the soil at the site of application of higher amounts of acid and physiologically acid fertilizers has an injurious effect only at the time the corn seeds germinate. Subsequently, however, when the plants are sufficiently strong, they manage to overcome the higher soil acidity and react positively to supplemental feeding.

Consequently, with the hill method of application of fertilizers it is important to isolate the seeds from direct contact with fertilizers during the germination period. This can be done by incorporating fertilizers in the soil at a short distance from the seeds -- on the side of the hill. An extra field experiment for corn demonstrated (Table 5) that the same amount of fertilizers when placed 3 cm from the seeds exerts almost no effect on the amount of corn germinated and that only a high double dose of NPK reduces germination from 72 - 59% of the total number of seeds planted. When the distance from the seeds was increased to 6 cm (Table 5), the same double dose of mineral fertilizers had no adverse effect on the germination and resulted in the greatest increase in the total yield of green mass per plot. With the application of fertilizers, acidity and salt concentration remained as high as in the preceding experiment in which fertilizers were placed in the soil together with the seeds. Thus, the field tests demonstrate that placing mineral fertilizers on sandy soils right in the holes (hills) with the seeds in even relatively small amounts (above 0.5 cntr/ha) markedly hinders germination because of substantial acidification of the soil at the site of application. Germination is checked when the titratable acidity of the water extract is 0.24 meq per 100 g

Table 5

Effect of spacing of fertilizers on corn germination and on composition of soil water extracts

Treatments[a]	Corn germination, %	Wt. of 40-day old plants on the plot, g	pH	Titratable acidity, meq per 100 g of soil	Concentration of salts, %
Without fertilizer (control)	72	325	5.9	0.034	0.02
Pc with 2 g alongside the seeds, 3 cm away	67	439	5.6	0.206	0.11
Pc plus Naa (2 g each) alongside the seeds, 3 cm away	64	510	5.3	0.450	0.18
Pc plus Naa (2 g each) plus Kx 1 g	70	725	5.3	0.400	0.21
Pc plus Naa (4 g each) plus Kx (2 g)	59	766	5.2	0.570	0.31
Pc plus Naa (4 g each) plus Kx (2 g) alongside the seeds, 6 cm away	78	1001	5.2	0.510	0.25

[a] For the symbols of the fertilizers, see note to Table 4.

of soil[1] and it progressively rises as this value grows.

The preliminary investigations (see Table 3) in which we recorded changes in soil acidity at intervals of 2 cm and the data of Table 4 support the conclusion that local acidification of sandy soils injurious to corn, according to data from water extracts, is about 0.35 meq of titratable acidity per 100 g of soil when fertilizers are placed in holes or drilled with the seeds.

LABORATORY INVESTIGATIONS

The increases in soil acidity caused by fertilizers varies not only with the amount, but also with the nature and form of the fertilizer. We conducted several additional laboratory investigations to determine the effect of various fertilizers and combinations of them on changes in acidity of sandy soils.

The experiment was set up using a modification of Tyulin's method of briefly exposing vessels to evaporation (3). Samples of dry soil weighing 200 g were mixed with fertilizers, placed in porcelain cups, and were left to stand for seven days at room temperature (20 - 23°C). Then soil water extracts were prepared in the ratios of 1 : 2.5 and 50 ml of filtrates were titrated with 0.02 N Na OH in the presence of phenolphthalein. The first series of tests was made with different amounts of ordinary superphosphate, potassium chloride, and ammonium nitrate. The results of these tests show that different fertilizers applied in the same amounts produce very diverse acidification effects on the soil. Just as in the field tests, the strongest soil acidification was caused by ammonium nitrate, somewhat less by superphosphate, and scarcely any by potassium chloride.

Since a titratable acidity of water extracts from sandy soils over 0.35 meq is injurious to germination and initial corn growth (as established in field tests), the maximally efficient amounts of fertilizers applied to the hills are as follows (according to the data of Table 6): for ammonium nitrate about 0.125% of the soil weight, for superphosphate about 0.5%, and for potassium chloride over 2%. However, an increase in the amount of potassium chloride, about 2% of the soil weight, may hamper germination by excessive salt concentration at the site of application. In shallow sands soil acidification caused by superphosphate has the same effect as in deep sands.

The data of these determinations of titratable acidity of water extracts can be used to establish effective amounts of mineral fertilizers when placed either in hills or banded together with seeds in various types of sandy soils. Applying this experimental technique for various fertilizers or mixtures suggested for use in the hill method of planting, it is possible (with four doses of fertilizers e. g., 0.1, 0.2; 0.4, and 0.6 g per 100 g of soil) to establish an orientation point on the acidity curve (from 0.3 - 0.35 meq per 100 g of soil). This point based on the soil titration curve will correspond to the efficient dose of fertilizer for our soil. It turned out, for example, that the optimum amount of ammonium nitrate combined with an equal measure of superphosphate for direct applications to hills on deep

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[1] To be more precise, inhibition of corn shoots occurs when the value of titratable acidity is higher than 24 meq per 100 g of soil because this acidity was determined not at the site where the fertilizer was applied, but in the 0 to 10 cm layers.

Table 6

Effect of amounts of various mineral fertilizers steamed in soil with evaporation changes in soil acidity (derived from titration of water extracts)

Fertilizer amounts, g per 100 g of dry soil	Titratable acidity, meq per 100 g soil				pH	
	Deep friable sands			Shallow sands	For superphosphate	
	For ammonium nitrate	For superphosphate	For potassium chloride	For superphosph.	Shallow sands	Deep sands
Without fertilizer	0.05	0.03	0.05	0.09	5.4	5.8
0.125	0.34	0.06	0.05	-	-	5.6
0.25	0.50	0.12	0.05	0.13	5.3	5.3
0.5	0.85	0.26	0.06	0.27	5.3	5.2
1.0	1.55	0.89	0.06	0.95	5.2	5.2
2.0	-	1.49	0.24	1.67	5.0	5.0

Table 7

Effect of fertilizer combinations and amounts on acidity of soil water extracts

Fertilizers[a]	Fertilizer amounts, g per 100 g of soil	Soil titratable acidity, meq per 100 g soil	pH
Without fertilizer	-	0.026	5.8
Superphosphate (Pc)	0.25	0.12	5.6
Pc + Kx	0.25 g each	0.12	5.5
Pc + Naa	0.25 g each	0.32	5.4
Naa + Pc + Kx	0.25 g each	0.40	5.4

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[a] For the symbols, see note to Table 4.

sands was 0.5% of the soil weight, whereas it was 0.65% in the case of NPK fertilizer.

The following formula may be used to convert these findings into kilograms per hectare:

$$Y = A \frac{500 \times H}{100 \times 1000} = A \times \frac{5 \times H}{1000} \text{ kg/ha,}$$

where A is the percentage of fertilizer that corresponds to the optimum (less than 0.35 meq) acidity of fertilized soil in the laboratory vessels and H is the number of hills per hectare, the soil weight in a single hill being 500 g.

Thus, it is evident from Table 7 that if the total quantity of ammonium nitrate and superphosphate in the laboratory vessels corresponding to the optimum soil acidity (0.32 meq) is 0.5%, then for 20,500 hills (spots) per hectare the permissible rate of application will be:

$$\frac{0.5 \times 5 \times 20{,}500}{1000} = 2.5 \times 20.5 = 51.25 \text{ kg/ha}$$

or 2.5 g of fertilizer per spot. When applied to grain crops in drills, one and one-half times or twice the amount of fertilizer are used.

THE EFFECT OF FORMS OF FERTILIZERS ON SOIL ACIDITY

To study the effect of various forms of fertilizers on the changes in acidity of sandy soils, we conducted the following series of experiments using the laboratory method.

We concluded from these experiments that with the local hill application of ammonia forms of nitrogen fertilizer the amount should not exceed 20-25 kg/ha and when possible, they should be replaced with inert forms such as potassium nitrate or sodium nitrate, the quantity of which can be doubled or even trebled without any ill effects. The potassium fertilizers in any form do not perceptibly acidify the soil.

Because of the present widespread use of organic mineral mixtures as fertilizers according to the hill method, we also investigated their effect on the changes in soil acidity. We found that the addition of humus and peat to phosphorus-potassium fertilizers at the rate of 1 or 2 metric tons/ha has almost no effect on the value of titratable acidity of sandy soils caused by mineral fertilizers alone. However, the addition of lime to the organic mineral mixture at the rate of 5 - 10% of the weight of superphosphate substantially lowers the soil acidity (by one-third or one-half) and raises the pH from 5.4 to 6.5.

This positive effect of small admixtures of lime was confirmed by numerous experiments at the station with drill application of superphosphate neutralized with chalk (4) and did not depend on organic fertilizers. Similar data relating to the effect of lime in lowering soil acidity have also been obtained with phosphorus-potassium fertilizers without the addition of organic substances.

The use of ground phosphate rock as a neutralizing agent did not lower the titratable acidity of the soil caused by the superphosphate.

CONCLUSIONS

1. Placing mineral fertilizers directly in drills (and especially in holes) together with the seeds causes marked acidification of podzolic sandy soils at the place where the fertilizers are applied. This inhibits germination and is frequently responsible for the low efficiency of the fertilizers themselves. The larger the amount of fertilizer applied, the stronger the acidification. It is caused by the activation of exchangeable acidity resulting from the addition of neutral salts (KCl) to the soil or from the acidity of the fertilizers themselves (superphosphate), and from the acidifying effect of the nitrification of nitrogen fertilizers applied in ammonia forms.

2. To determine the most effective rate for the hill method of applying fertilizers together with seeds on sandy soils, preliminary composting of fertilizers with soil for a brief period (in vessels), taking into account the acidification of water extracts caused by the various fertilizers is suggested. For sandy soils the value of acidification injurious to germination lies above 0.3 meq per 100 g of soil.

3. To reduce excessive (injurious to young plants) soil acidification, fertilizers should be mixed with powdered chalk at the rate of 5 to 10% of the fertilizer weight before they are placed in seed rows or hills. Mixing mineral fertilizers with humus or peat (without lime) does not reduce the acidity of soil caused by the application of fertilizers.

4. Placing mineral fertilizers alongside a seed row or hill at the distance of 5-6 cm from the seeds does not inhibit germination (particularly corn seeds). With this method the amount of mineral fertilizers can be doubled or even trebled without any ill effects.

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COLOR CHANGES OF NORTHERN SURFACE SOILS

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Soils of the tundra and sod-podzolic zones are found in large areas of the Soviet Union. Because they were formed under severe climate, their agricultural properties are poor. If agriculture is to expand and develop in the north, these soils must be thoroughly studied.

In the summer northern soils are poorly heated; the depth of heat penetration is even less. This is due to the relatively weak solar nsulation and the very low immissivity of the soils owing to their light grey color. In order to increase their fertility it is first necessary to improve their thermal properties. Supplying a darker color to the soils is the most effective method of increasing immissivity. The thermal and nutritive regime of light grey soils in the north can be substantially improved when this method is used in conjunction with necessary agricultural and reclamation work.

Soil temperature has been increased by mulching in the experiments of Balashov (4), Kan (5), Tsyplenkin (6), Aleksandrov and Kurtener (3), and of the authors of this article (1, 2).

Experiments were conducted on experimental plots of the Kola Branch of the USSR Academy of Sciences. Darkening soils was accomplished by applying carbon black (5 metric tons/ha) or powdered peat (5 metric tons/ha). Soot and peat were applied to soil in a thin ayer. Powdered chalk (5 metric tons/ha) was used to give a white color to the soil surface. ndividual plots were fertilized.

The experiment began on June 13, 1955 with the broadcasting of oats. Soil surface emperatures were measured by an ordinary mercury thermometer. A Savvinov thermometer was used to measure at depths of 5, 10, 20 and 40 cm. Available forms of nitrogen, phosphorus and potassium in soil were measured.

First to be considered is the temperature regime of experimental plot soils (Table 1). Soil surface temperature varies noticeably on all plots during the course of the day. In clear weather it increases strongly until midday and then falls off at an even rate toward evening. Soil temperature at a depth of 5 cm undergoes a similar change but the amplitude is considerably smaller. The maximum does not occur at 1300 hours, as on the surface, but at 1600 hours. Soil temperature at a depth of 10 cm is approximately the same at a depth of 5 cm, but the amplitude is even smaller and the maximum occurs at 1900 hours. At depths of 20 and 40 cm the soil temperature is still lower and the amplitudes continue to decrease. The maximum is observed even later, at 2200 hours. Thus, the temperature maximum gradually shifts with depth from 1300 hours at the surface to 2200 hours at a depth of 40 cm. A heating in depth therefore takes place during the daily absorption of solar heat by the soil. Temperature on the surface and at all depths decreases when the soil is colored with chalk. Applications of powdered peat and carbon black result in temperature increases at all depths. On a clear sunny day the surface temperature of the black-colored plots increases rapidly from the early morning hours and thereafter differs considerably from the uncolored plots. There is no substantial difference in surface temperatures in the second half of the day. Consequently, the considerable increase in the immissivity of soils after being given a dark color occurs in the first half of the day. Then the solar heat absorbed by the soil is passed downward by thermal conductivity and the lower-lying horizons are correspondingly better heated. The soil temperature regime on the colored and non-colored plots is less changeable in overcast weather (Table 2) than in clear weather. The temperature maximum at midday in overcast weather is the same as in clear weather. The positive influence of coloring on soil temperature is considerably less in overcast weather than in clear weather.

The influence of surface coloring of soils on their heating characteristics and temperature was studied when there was a grain crop in the field (the plots were planted in oats). Taking this into consideration, the observed effect must be regarded as completely apparent and worthy of study. It should also be emphasized that the development of the root system on the dark-colored plots progressed more vigorously than on the non-colored plots. This

Table 1

Influence of color on soil temperature

Plots	Depth, cm	Hours of observation, July 29, 1955						Weather
		7	10	13	16	19	22	
Not colored	0	14,0	26,0	33,0	24,0	17,0	11,0	Clear sunny
	5	15,0	15,6	17,5	19,5	18,5	16,5	
	10	15,0	15,0	15,0	16,5	16,6	16,5	
	20	14,0	14,0	14,0	14,5	14,5	14,7	
	40	13,5	13,5	13,5	13,5	13,5	13,8	
Colored with chalk	0	13,0	23,0	24,0	19,0	14,0	10,0	"
	5	14,0	14,5	16,0	16,5	16,0	15,0	
	10	14,0	14,0	14,0	14,5	14,5	14,5	
	20	14,0	14,0	14,0	14,0	14,2	14,2	
	40	12,5	12,5	12,5	12,5	12,5	12,5	
Colored with peat	0	20,0	25,0	35, 0	24,0	18,0	11,0	Clear sunny
	5	15,0	15,0	16,0	17,5	17,0	16,0	
	10	15,5	15,5	15,5	16, 0	16,3	16,6	
	20	14,5	14,5	14, 5	14, 5	15,0	15,0	
	40	13,5	13,5	13, *	43, 5	13,5	13,5	
Colored with carbon black	0	22,0	36,0	39,5	25,0	18,0	12,0	
	5	15,2	15,6	18,0	19,0	18,1	17,0	
	10	15,0	15,0	16,0	16,5	16,5	16,5	
	20	15,0	15,0	15,0	15,9	15,9	16,0	
	40	14,0	14,0	14,0	14,0	14,5	14,5	

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* Not legible in original Russian article.

Note: Comma represents decimal point.

influence was considerably higher on a bare field than on one planted in crops (1, 2).

Giving a soil surface a dark color also changes the nutritive regime of the soil. In our analysis we determined the following at different times: nitrates, by the colorimetric-disulfophenol method; ammonium, by the Nessler reagent; phosphates, by the Kirsanov method; potassium, by the Peyve method. Nitrate data are given in Table 3.

The nitrate contents in the soil of the non-colored and non-fertilized plots is extremely low and changes little with time. In the non-colored but fertilized plots, however, the nitrate content increased sharply not only in the 0-15 cm layer, but in the 20-35 cm layer as well. It underwent noticeable changes with time. The nitrate content of the soil increased somewhat under the influence of an application of chalk. This increase probably is not connected with the thermal regime but rather with a change in the reaction of the soil solution. When the soil surface was colored with powdered peat the nitrate content exceeded that of the non-colored plots by 4-16 times. Approximately the same phenomenon was observed when the soil surface was darkened with carbon black.

The sharp increase of nitrates in the soil as a result of the dark coloring is due to the marked improvement in the thermal regime. This is favorably reflected in the nitrification process.

Let us examine how the coloring of soils influences their ammonium content (Table 4). The ammonium content in the soil varies greatly during the summer. It progressively increases quantitatively from the first observation to the last, in a majority of cases.

A distinguishing difference between the behavior of ammonium and nitrates is that ammonium is present at a depth of 20-35 cm in the same quantities as in the 0-15 cm layer. On the other hand there is very little nitrate in the 20-35 cm layer. Coloring the soil with powdered peat and carbon black resulted in an increase in the ammonium content, but on a smaller scale than the increase in nitrates.

Table 2

Influence of color on soil temperature

Plots	Depth, cm	Hours of observation, July 30, 1955						Weather
		7	10	13	16	19	22	
Not colored	0	12,0	19,0	24,0	17,0	14,0	13,0	Overcast
	5	12,0	13,0	15,5	16,0	15,0	14,5	
	10	13,5	13,5	14,0	14,5	14,5	14,0	
	20	13,4	13,0	13,0	13,0	13,0	13,0	
	40	13,0	13,0	12,5	12,5	12,5	12,5	
Colored with chalk	0	9,0	15,0	19,0	14,0	12,0	11,0	
	5	11,0	12,0	13,5	13,7	13,4	13,0	
	10	12,0	12,0	12,2	12,5	12,5	12,5	
	20	12,7	12,5	12,5	12,5	12,5	12,5	
	40	12,0	12,0	12,0	12,0	12,0	11,5	
Colored with peat	0	13,0	21,5	26,0	17,0	14,0	13,0	
	5	12,2	13,0	14,6	15,0	14,5	14,0	Overcast
	10	14,2	14,0	14,1	14,5	14,5	14,5	
	20	13,5	13,2	13,0	13,4	13,5	13,5	
	40	13,0	12,5	12,5	12,5	12,5	12,5	
Colored with carbon black	0	14,0	24,2	27,1	18,2	15,0	15,0	
	5	13,0	13,5	15,3	15,8	15,3	15,0	"
	10	13,5	13,5	14,0	14,5	14,5	14,5	
	20	14,1	14,0	14,0	14,0	14,1	14,0	
	40	14,0	13,5	13,5	13,5	13,5	13,5	

Note: Comma represents decimal point.

Table 3

Nitrate content, mg per 100 g of dry soil

Plots	Depth, cm	Measurement dates in 1955			
		July 15	July 23	Aug. 10	Aug. 20
Not colored	0—15	1,1	1,6	0,7	0,4
	20—35	0,5	0,2	0,3	Traces
Colored with chalk	0—15	—	1,7	1,5	0,6
	20—35	—	0,2	0,4	Traces
Colored with peat	0—15	—	6,0	7,2	5,6
	20—35	—	0,2	0,7	0,7
Colored with carbon black	0—15	—	6,4	5,0	20,4
	20—35	—	0,2	0,6	0,9
Colored with carbon black and fertilized (NPK)	0—15	—	11,8	10,2	25,7
	20—35	—	0,5	1,0	1,9
Not colored, fertilized (NPK)	0—15	14,3	10,8	9,4	26,6
	20—35	7,9	1,2	1,8	2,3

This difference in the dynamics of NO_3 and NH_4 after the soil had been given a dark color is probably due to the fact that the ammonification and the closely associated nitrification transpire vigorously in a period of especially favorable hydrothermal conditions. Under less favorable conditions the nitrification lags considerably behind the ammonification.

Available phosphate content in the soil is shown by the data in Table 5. The amount of phosphates in the soil changes little with time. Coloring exercises an influence on phosphate content, but to a lesser degree than on nitrate

Table 4

Ammonium content, mg per 100 g of dry soil

Plots	Depth, cm	Measurement dates in 1955			
		July 15	July 23	Aug. 10	Aug. 20
Not colored	0—15	1,21	1,4	6,3	7,4
	20—35	0,72	0,7	—	6,6
Colored with chalk	0—15	—	1,5	6,6	5,9
	20—35	—	0,5	6,1	5,3
Colored with peat	0—15	—	0,9	5,8	8,8
	20—35	—	0,6	7,8	6,9
Colored with carbon black	0—15	—	8,2	9,2	12,1
	20—35	—	5,1	5,1	7,2
Colored with carbon black and fertilized (NPK)	0—15	—	9,8	14,5	9,2
	20—35	—	5,6	7,3	8,0
Not colored, fertilized (NPK)	0—15	0,86	6,5	8,8	6,9
	20—35	0,78	4,6	6,6	7,8

Table 5

Available phosphorous in mg of P_2O_5 per 100 g of dry soil
(Kirsanov method)

Plots	Depth, cm	Measurement dates in 1955			
		July 15	July 23	Aug. 10	Aug. 20
Not colored	0—15	9,74	7,0	6,2	7,6
	20—35	6,28	6,2	5,0	—
Colored with chalk	0—15	—	5,0	4,8	6,0
	20—35	—	5,2	4,3	6,1
Colored with peat	0—15	—	10,0	7,4	12,7
	20—35	—	6,5	4,3	7,1
Colored with carbon black	0—15	—	10,5	7,2	7,3
	20—35	—	9,0	8,5	8,3
Colored with carbon black and fertilized (NPK)	0—15	—	10,6	7,3	7,3
	20—35	—	5,5	5,2	6,6
Not colored, fertilized (NPK)	0—15	6,2	10,1	6,8	5,5
	20—35	4,4	7,5	6,5	6,6

content. Chalk decreased the amount of phosphates. The phosphate content was somewhat greater on the non-colored plots. The soils colored with peat, however, contain approximately 1-1/2 times more phosphates than do the non-colored ones. The same amount of phosphates are also present in soils colored with carbon black, but with the single difference that there are more phosphates in the 20-35 cm layer than in the plots colored with peat. The application of NPK to the soil did not change the amount of phosphates or the character of their behavior. Available potassium also increases under the influence of coloring (Table 6). This is due to an intensification of biochemical reactions resulting from the warming of the soils.

Thus, the nutritive regime of the soils improved noticeably after application of the black color; this had a favorable effect on plant development.

In 1955, oats were sown on all plots on the same day (July 13), but germination took place on different days on the different plots: it was two days earlier on the plots colored by carbon black and powdered peat than on the non-

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Note: Comma represents decimal point.

Table 6

Available potassium in mg of K_2O per 100 g of dry soil

Plots	Depth, cm	Measurement dates in 1955			
		July 15	July 23	Aug. 10	Aug. 20
Not colored	0—15	7,3	7,6	4,0	0,0
	20—35	5,5	0	0	0,0
Colored with chalk	0—15		7,6	6,7	0,0
	20—35		4,7	—	0,0
Colored with peat	0—15		12,6	11,1	7,7
	20—35		6,3	6,7	—
Colored with carbon black	0—15		9,5	8,0	7,7
	20—35		7,6	8,0	—
Colored with carbon and fertilizer (NPK)	0—15		19,0	10,0	11,5
	20—35		4,7	5,0	—
Not colored and fertilized (NPK)	0—15	14,6	12,6	13,3	7,7
	20—35	5,5	6,3	6,7	7,7

Table 7

Content of N, P_2O_5 and K_2O in top portion of oats,
percentage of dry weight

Plots	August 10, 1955			August 20, 1955		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Not colored	4,18	0,80	4,90	3,62	0,53	5,18
Colored with chalk	2,95	0,43	3,56	2,56	0,44	4,08
Colored with peat	5,68	1,18	6,01	4,46	0,76	7,25
Colored w/c. black	4,64	1,02	4,97	4,49	0,76	5,53
Not colored, fertilized	5,24	0,98	4,88	4,39	0,67	5,88
Colored with carbon b., fertilized	5,81	1,28	5,17	5,68	0,86	6,41

Note: Comma represents decimal point.

colored plots. The further development of the root system of the oats also progressed more actively on dark colored plots. As a result, the oats tillered on the colored plots on August 9-10, while on the non-colored plots this did not occur until September 1. The oat leaves on the non-colored plots were noticeably paler than on plots colored with carbon black and peat, where the oats had a dark green color. On August 28 the oats were 10-20 cm high on the non-colored plots, 10-20 cm high on those colored by chalk, and 40-50 cm high on those colored by peat and carbon black.

Other evidence of the increase in biochemical activity under the influence of a black coloring is the fact that the plants absorb more nitrogen, phosphorus and potassium from the soil during their development and growth on the colored plots than on plots with a natural color. Table 7 gives analytical data in support of this.

An analysis of plants by phases -- three pairs of leaves and a shoot -- indicates that the coloring of a soil surface with powdered peat and carbon black increases the plant intake of the indicated nutrients from the soils. The chalk, however, causes an opposite effect. Thus, the black coloring of soils not only improves conditions for the development of the vegetative part of the plants, but also facilitates their enrichment with nitrogen and inorganic elements. These circumstances are extremely important for the North, since at the same time they improve the food and forage qualities of cultivated plants.

There are almost unlimited supplies of peat in the USSR to the north of the Arctic Circle. These can be successfully used in powdered form for surface application on soils. The peat can also be used as a coloring and warming material and as an organic fertilizer.

The applications of peat recommended in practice are completely adequate even for a double surface application in the course of a growing season.

CONCLUSIONS

1. Soils, given a dark color, absorb more solar heat and warm up better than do soils with a light grey natural color. This is true in both clear and cloudy weather.

2. When soils are given a dark color there is an intensification of the processes of mobilization of nutritive substances in the soil. As a result there is an increase in the soil content of nitrates, ammonium, available phosphorus and available potassium.

3. When the thermal and nutritional regime of the soils was improved, the oats developed better on the plots with a dark color than on the non-colored plots.

4. The plant intake of nutritive substances from the soil takes place (by phases of development) more intensively on dark colored plots than on the non-colored plots.

5. The problem of coloring soils can be of very great importance for agriculture in the north. Henceforth we must conduct field experiments with the coloring of soils using various crops (in association with other measures) and research on the influence of these measures on soil processes.

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DYNAMICS OF NITRATES AND MOISTURE IN ORDINARY CHERNOZEMS OF DIFFERENT LAND USES IN THE KUYBYSHEV OBLAST'

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This paper presents observational data concerning the dynamics of nitrates and soil moisture over a period of two growing seasons for several fields in a nine-field crop rotation system and for steppe plots, abandoned land and fallow experimental fields of the Kuybyshev Agricultural Institute.

Comparative observations of the dynamics of soil fertility were conducted in the following plots: 1. Second year grasses (Field No. 6) of the nine-field crop rotation; 2. Fallow (Field No. 4); 3. Rye (Field No. 1); 4. Corn (Field No. 2) 5. Permanently non-moved, nine-year abandoned land; 6. Permanently fallow (nine-year); 7. Virgin steppe; 8. Forest plot of cut-leaf maple, intermixed with oak.

Observations begun in 1954 were completed in the spring of 1956. Soil samples were correlated with the stages of crop development; after the crop study, observations were conducted in the following periods: 1) when soil moisture was low and the temperature high (July); 2) when there was low moisture and a lower temperature (September); 3) when there was low moisture and low temperature (October). Each time the samples were taken from the identical profile, of which a 35 - 40 cm section had been cut away.

The soil cover of all plots was ordinary chernozem, thick, clay loam, on carbonaceous clays with a low effervescence line.

A few data characterizing the soils are given in Tables 1 and 2. The Institute's experimental fields consist of clays and fine clay loams with a predominance of medium and fine silt particles.

Data obtained indicate a high humus content in the forest and steppe soils. In the tilled horizons of the chernozem humus content amounts to 7 - 7.5%; this indicates a loss (up to 25%) through cultivation over a period of several decades.

The humus content decreases gradually with depth of profile and at a depth of 1 meter it is 0.5%. The major part of the humus occurs in a soil layer which is as much as 60 cm thick. The amount of solid residue is insignificant and the maximum content is obtained in the autumn in the 0-10 cm layer. The total alkalinity in this layer is 0.043%, increasing somewhat with depth.

In beginning our interpretation of the dynamics of soil fertility of ordinary chernozems under various conditions, it is necessary above all to determine the meterological peculiarities of the period of observations.

The distribution of precipitation varied considerably for individual years (Table 3). Therefore, the region under study should be included in the zone of fluctuating and deficient moisture. In 1951, the precipitation amounted to 320 mm in 1944 -- 531 mm.

The maximum daily rainfall totals reach 68.3 mm (1953) and are observed in the hot season of the year. Such maxima are repeated rather frequently. Heavy showers are accompanied by considerable sheet erosion of the soil mass and gully development. After showers one can see small and large rills everywhere, and there is an accumulation of fine soil material in isolated areas protected by timber plantings and isolated clumps of vegetation, rocks, ridges, etc.

The distribution of the monthly precipitation occurring in the years of observation is of great interest (Table 4).

The maximum amount of precipitation occurs in the warm months (April-October), the least from November through March.

The first part of the growing season (May-June) is often characterized by prolonged drought; this is of exceptional importance for the periods of sowing and cultivation of

Table 1

Particle size analysis of ordinary chernozems, % of soil weight

Horizon	Depth, cm	Diameter of particles, mm							
		1–0,25	0,25–0,05	0,05–0,01	0,01–0,005	0,005–0,001	<0,001	>0,01	<0,01
A_1	10–20	1,0	14,5	18,2	25,7	22,0	18,5	33,7	66,3
B	40–50	1,5	10,8	20,3	26,8	23,3	17,2	32,6	67,4
C	100–110	2,0	13,0	19,0	22,1	24,8	19,1	34,0	66,0

Note: Comma represents decimal point.

Table 2

Chemical and moisture contents of ordinary fine clay loam chernozem, % of soil weight

Location	Depth, cm	Hygroscopic moisture	Maximum hygroscopicity	Humus (according to Tyurin)	Dry residue	Mineral residue	Water soluble CaO	Total alkalinity	pH
Plateau	0–10	6,6	11,0	9,9	0,11	0,048	0,035	0,043	7,2
Experimental field	20–30	6,6	10,8	7,7	0,065	0,032	0,026	0,053	7,2
	30–40	6,6	11,4	6,5	0,050	0,028	0,025	0,055	7,2
	50–60	6,6	—	5,4	0,043	0,022	0,018	—	7,2
	65–70	—	—	1,2	0,046	0,021	0,017	—	7,2
	100–110	—	—	0,5	—	—	—	—	—

Note: Comma represents decimal point.

Table 3

Annual precipitation for the past decade, mm

1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
412	531	524	396	499	454	403	382	320	422	481	360

individual crops. For production of winter crops the most important precipitation occurs in August and in the spring, in the period from the beginning of plant development until the spikes of grain appear.

The snow cover is of extreme and varied importance for the processes of soil formation and the cultivation of agricultural crops. The snow cover is a source of moisture and an insulation for winter crops. The accumulation of the snow cover begins at the end of November, the thaw in March. The clearly pronounced microrelief causes an uneven deposition of the snow over the area; even in the snowiest winter (1956) the snow accumulated considerably less on the level areas. The snow is concentrated in depressions and wooded zones causing greater leaching of the soils in these places. The average depth of the snow cover is 40 - 60 cm; in 1956 it reached 1 meter, while in the wooded zones it reached 3 meters.

MOISTURE OF THE AIR AND SOILS

The relative humidity of the air is sufficiently high for the growth of plants, but its minima are of great importance; decreasing during the daytime hours the humidity drops to the seriously injurious value of 19% when

Table 4

Monthly distribution of precipitation in 1954-1955

Months	Precipitation amount, mm		Days with precipitation		Days with more than 10 mm precipitation	
	1954	1955	1954	1955	1954	1955
January	22.7	54.7	11	15	--	1
February	7.8	75.8	5	19	--	1
March	10.0	12.6	6	2	--	--
April	35.3	16.6	8	7	1	--
May	43.8	27.6	8	4	1	1
June	29.9	17.1	7	3	--	1
July	39.4	38.2	7	7	1	1
August	20.4	54.0	5	5	--	1
September	59.0	18.8	8	4	2	1
October	56.6	31.4	16	4	1	1
November	26.2	20.6	7	5	1	--
December	9.8		3	--	--	--

Table 5

Moisture in ordinary chernozem used for various agricultural purposes, % soil weight

Field No.	Land use	Depth, cm	1954		1955							
			June 9	Sept. 17	Crop	Depth, cm	Apr. 4	Apr. 30	July 7	Sept. 9	Oct. 27	Freezing Depth, cm
1	Fallow	0—10	29,7	27,3	Rye	0—20	70,6	20,3	20,4	22,5	—	10—25
		45—55	27,8	20,7		45—55	30,1	18,2	17,8	20,3	—	
2	Buckwheat	0—10	29,0	15,6	Sunflowers	0—10	55,8	19,3		15,4	—	15—45
		40—50	24,8	16,3		40—50	32,0	18,1		19,3	—	
		80—90	20,4	16,4	Corn	0—20	24,0	23,0	10,8	14,9	—	
3	Millet	0—10	25,5	12,3		35—45	—	18,8	17,1	15,1	—	
		35—45	26,7	14,1	Fallow	0—10	—	18,7	17,3	—	25,3	
4	Sunflowers	0—10	25,6	14,6		30—40	—	32,3	29,8	—	28,5	
		40—50	27,3	15,1	Permanent fallow	0—20	—		22,8	20.5	22,5	
						35—45	—		24,0	27,4	27,4	
					Abandoned land	0—10	80,0		15,3	18,5	18.5	30—50
						35—45	32,0		18,7	18,8	18.1	
						50—60	20,1		—	17.3	17,2	
					Cut-leaf maple	0—5	75,2	—	35,0	58,7	28,1	0—0
						15—2	48,3	—	27,0	23,7	27.3	
						30—40	35,1	—	22,7	20.5	23,4	
						65—75	28,1	—	20,0	21,2	22,1	
					Steppe	0—5	72,0	—	27,7	16,4	20,8	20—45
						15—20	42,0	—	34,0	9,3	18,3	
						30—40	30,0	—	22,6	18.5	—	
						65—70	24,0	—	18,7	16,4	—	
						140—150	15,0					
6	Grasses, third year	0—10	20,0	11,3					13,0			
		35—45	20,8	17,4					14,3			

Note: Comma represents decimal point.

he air temperature is above 30°C and the oil temperature is about 70°C. The lowest elative humidity of the atmosphere is observed in May and June (20 - 35%). At these mes the soil moisture sharply decreases to a depth of 80 cm. Below that level it changes little (Table 5).

Meteorological conditions varied in 1954 and 1955 and this was reflected in the yield of field crops. The fall of 1953 was dry, the winter early, and when winter set in there was only a small reserve of moisture in the soil. The spring of 1954 was favorable, and the soil moisture in May was at field capacity. The summer of 1954 was excessively dry and this had a negative effect on soil processes and on the yield of agricultural crops; toward the end of the summer the soil moisture was one and one-half times the value of maximum hygroscopicity, especially in fields sown to millet, sunflower and alfalfa; an exception was the fallow field, where the moisture supply differed little from that of the spring (Table 5). Black fallow fields locally assimilated enough of the available moisture for winter crops, despite the arid summer. In the other fields we did not determine the available moisture content during the dry season. The autumn of 1954 and the spring of 1955 were moist and this was favorably reflected in the development and growth of plants. A rather prolonged rainless period in the summer of 1955 somewhat retarded the growth of plants; soil moisture at the beginning of August reached the critical moisture level for wilting of plants and it was not until after a heavy rain on August 8 (40.2 mm) that field crops recuperated to any appreciable extent.

The autumn of 1955 was characterized by rather high temperatures and low humidity, the upper horizons attaining one and one-half times maximum hygroscopicity, especially in fields sown to corn and sunflowers (14-15%); in the lower horizons the soil moisture in all crop rotated fields was identical (17 - 18%). The abundant winter precipitation of 1956 and gradual melting of the snow saturated the soils to a depth of 150 cm, while in the lower horizons a gradual increase in moisture from the winter to the summer was observed (Table 6).

DYNAMICS OF NITRATES

Of considerable interest is the nitrate regime for the various agricultural crops being rotated. Their migration occurs with varying intensity. The data in Table 7 show adequate nitrate content in June in all rotation fields; there was more nitrate in the upper horizon in the cornfield than in the fallow field; the July observations detected a decrease in nitrates for all crops with maximum accumulation in the fallow field.

Light but frequent loosening of the black fallow under experimental conditions facilitated the intensive formation of nitrates (more than 500 mg/kg of soil), since such cultivation leads to increased aeration, moisture supply and also stimulates the activity of microorganisms and increases the content of nitrate nitrogen in the upper soil horizon (See Fig. 1).

Table 6

Soil moisture in ordinary chernozem used for various forms of land use (1956)

Depth, cm	Winter crop			Idle Land			Forest			Steppe			Permanent fallow		
	March 20	April 20	May 9	March 20	April 20	May 9	March 22	April 20	May 9	March 22	April 20	May 9	March 20	April 20	May 9
0–10	30,2	51,9	36,4	19,0	37,0	40,7	48,5	65,0	45,0	32,0	35,0	40,7	32,2	48,3	37,3
20–30	27,1	40,0	37,0	22,0	35,0	36,1	25,7	34,5	39,0	28,1	32,0	35,0	29,5	41,1	37,2
40–50	24,3	29,0	36,3	24,0	30,0	33,2	18,3	34,0	30,1	26,1	24,0	33,0	25,3	30,0	37,1
65–70	22,1	26,0	35,3	22,8	26,3	33,5	16,3	28,0	26,0	22,8	25,0	32,8	23,2	—	34,5
100–110	18,8	23,0	27,9	16,2	18,1	26,6	14,8	18,7	24,2	15,5	26,0	28,3	20,3	—	27,9
140–150	20,0	22,0	20,1			20,1						20,8			21,1
160–170						18,3						18,3			

Note: Comma represents decimal point.

Table 7

Dynamics of nitrogenous fertilizer in chernozem soil in various kinds of land use, mg/kg

Field No.	Land use	Depth, cm	Date of Sampling						
			1955					1956	Total humus content
			June 30	July 7	June 22	Sept. 9	Oct. 27	May 9	
1	Rye	0—10	18	14		22	31	—	7,0
		30—40	33	20		Trace	3	—	5,3
2	Corn	0—10	84	22		14	Not det.	—	7,1
		30—40	16	Not det.		17		—	5,3
4	Fallow	0—10	67	360		Not det.	226	Trace	
		30—40	69	220			177	12,4	
	Permanent fallow	0—10	96	122		157	117	72,4	7,6
		30—40	Not det.	173		17	77	Traces	5,4
		50—60	"	188		Not det.	14	"	3,1
		100—110	"	120			114	27,4	
	Permanent abandoned land	0—10	Negative	Trace		Negative	Negative	Traces	10,0
		10—20	"	"		"	"	Negative	
		20—30	"	"		"	"		5,4
		30—40	"	"		"	"	"	
		50—60	"	"		"	"	"	1,2
	Steppe	0—5	Trace	6		51	Not det.	"	9,7
		20—30	Negative	Negative		18	"		7,9
		30—40	"	"		5	"		6,3
		40—50	"	"		Negative	"		5,8
	Maple	0—5	Not det.	120		48	"		
		15—20	"	Negative		Negative	"		
		30—40	"	"		"	"		
	Maple, mixed with oak	65—75	"	"		"	"		
		0—10	12	66		20	30		13,6
		20—30	10	5		7	28		12,4
		30—40	Negative	Negative		2	24		13,4

Note: Comma represents decimal point.

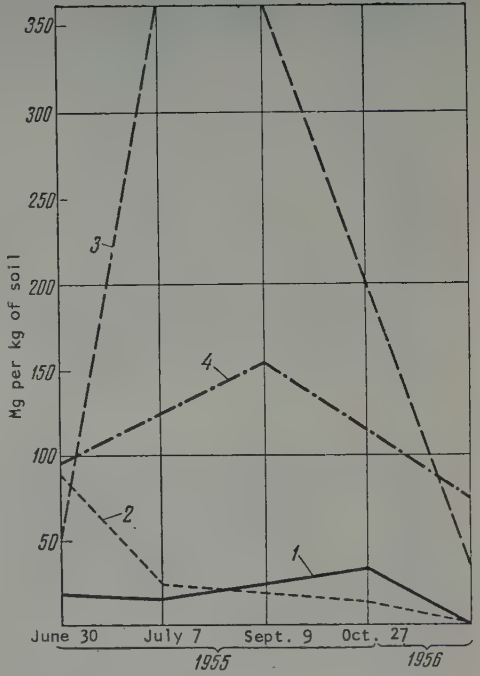

Fig. 1. Dynamics of nitrate nitrogen in the 0 to 10 cm layer.

1 -- rye; 2 -- corn; 3 -- ordinary fallow; 4 -- permanent fallow.

The maximum content of nitrates (and other available forms of nutrients) was observed in the 0 to 10 cm layer in all fields of the crop rotation system. Therefore, similar activity transpires with maximum intensity in the upper horizons.

The accumulation of nitrate nitrogen in the upper horizon allows the plants to receive nutrients in the first phases of their development when the need for them is greatest. These conditions were not observed when various depths of the plowing were used since the lower horizons do not provide a plant with all of its nutrients in the first phases of development; the overturned layers, exposed to atmosphere, once more accumulate available forms of nutrients. However, by this time the plant has already passed the tillering phase. As the plant develops further it again encounters insufficient nutrients in the lower horizons. Thus, deep cultivation with a moldboard results in the artificial starvation of plants even when there are adequate amounts of nutrients in the soil. This also explains in part the desire by individual researchers to replace ordinary cultivation methods with those not using a moldboard.

Winter rye, planted on fallow ground does not use all of the nitrates while it is growing; this same feature was noted in the corn field, although considerably less nitrate remained by the end of the growing season (Table 7). The maximum intensity of nitrification was observed at the end of July, and inasmuch as the fall of 1955 was warm, the process continued until the end of October and with the coming of winter, the soils contained a considerable amount of nutrients.

The determination of nitrates during the period when the winter crops were leafing (October 27) indicates that there was a considerable nitrate content to a depth of 40 cm with considerably less near the roots (168.6 mg/kg) than the average for the soil as a whole (225 mg/kg). Such a quantity of nitrates in a field of winter crops had not been noted previously in the late autumn in the soils of the Trans-Volga area. In the early spring of 1956 only traces of nitrates were detected in the 0 - 10 cm layer of this same plot, but the 30 - 40 cm layer contained 12.4 mg/kg. Consequently, the autumn supply of nitrates had been depleted during the winter. A significant nitrate content was noted in the spring in the 0 - 5 cm layer of the fallow plot, where the rapid increase in temperature on the barren soil surface provides optimum conditions for micro-organism activity.

The biological conditions on the permanently fallow and abandoned land differ sharply from those which were observed in the rotated fields. There is a sharp difference in soil moisture conditions together with movement of water, air and nutrients. The soils of the fallow field were always kept in a mellow condition because in this state air penetration is assured, as is the relatively high water permeability of the upper soil horizons with their considerable water retaining capacity and low capillarity.

The soil organic content of the permanently fallow ground is 2.3% less than in the soils of the abandoned land plot; this is explained by the intensive mineralization in the absence of organic matter increases. In the lower horizons (50 - 60 cm) the humus content in the fallow field is 1.98% greater than in the abandoned field, indicating greater mobility of organic matter when there is prolonged fallowing.

Simultaneously with the decrease in the total organic matter content in the upper horizons, a significant accumulation of nitrate nitrogen to a depth of 100 cm was noted. Almost the same amount was contained in the abandoned plot and the virgin steppe; consequently, over the nine-year period the humus content of the abandoned land increased by approximately 30 - 40%; this was associated with a constant accumulation of surface and subsurface organic matter considerably in excess of the amount of natural vegetation.

There were no nitrates in the soils of the abandoned plot throughout the entire period during which observations were made; in the steppe areas an accumulation of nitrate nitrogen was noted to a depth of 40 cm (Table 7) by autumn.

Our observations for phosphates indicate that they have low availability in the soils of the rotated fields. Water-soluble phosphates are found only in the forest litter amounting to 4.86 mg/kg of soil and in the 0 - 10 cm layer of the abandoned plot 3.37 mg/kg.

CONCLUSIONS

1. The dynamics of the water supply available to plants were dissimilar in the various rotation fields; in the upper horizons the amount of water accumulated depends on meteorological conditions and drops sharply in the dry season, reaching a value of one and one-half times the maximum hygroscopicity. Considerable decrease of moisture in the corn field is found, the least change taking place in the field of winter rye.

2. The amplitude of moisture fluctuation decreases with depth and becomes insignificant in the 100 - 110 cm horizon in all rotation fields. Under experimental conditions

the moisture loss in the soils of the fallow field was equal to the moisture intake because of the absence of transpiration, and because the soil moisture during the prolonged dry season did not drop below 25%.

3. The soils of the abandoned land and virgin steppe had a low moisture content in the dry season since the compacted horizons increased its evaporation to a greater extent in the first case than in the second.

4. Ordinary chernozems contained enough nitrates, water-soluble Ca and other compounds for plants; there was a deficiency of available phosphates in all the rotation fields and it was greater in the wooded and abandoned land plots.

5. The soils studied had a high nitrification capacity and when allowed to fallow, accumulated a large amount of nitrates which were only partially used by cultivated plants in the following years; this made possible the use of nitrogenous fertilizers in small applications.

6. Light but frequent loosening of the fallowed soil insures accumulation of nitrates at a rate of 500 mg/kg of soil.

7. A significant nitrate content was observed in the corn field in the spring, but by the end of the growing season its content was lower than in the field with winter crops.

8. Autumn observations confirmed the accumulation of nitrates during the long, warm, autumn period of 1955 and a full supply of nitrates before growth was resumed.

EFFECT OF THE MAJOR BIOLOGICAL FACTORS ON AIR COMPOSITION OF ALLUVIAL SOILS IN THE KLYAZ'MA RIVER FLOOD PLAIN[1]

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A knowledge of the role played by biological factors in changes in the air composition of the soil is of great importance in solving the problems involved in improving fertility (3, 7, 8, 9). The "living" soil must be studied together with its plants, microorganisms and invertebrate animals. The synthesis of organic matter by plants and microbes and the decomposition of organic and mineral fractions of the soil by microorganisms takes place only when there is a certain content of oxygen, carbon dioxide, and nitrogen both in the soil and in the atmospheric air.

In this paper, which concludes three years of investigation of gas and water relations of alluvial soils in the Klyaz'ma River flood plain, the role of soil microorganisms and plant roots in carbon dioxide formation was studied (10).

Soil samples with almost undisturbed structure were taken with a tapered auger having a 200 ml capacity (5.04 cm in diameter, and 10 cm high). This auger was manufactured on the principle of the Doyarenko auger (3). The samples were carefully wrapped in wax paper and delivered to the laboratory within 40 to 50 minutes. After rapid separation of the roots and sifting through a 2.5 mm opening sieve, 25 g of soil were placed in a glass chamber (Fig. 1). This chamber of 135 ml in volume, had two stopcocks a and b which were opened at first. Then the opening c 2 cm in diameter was tightly closed with a rubber stopper at the water lock. The stopcocks a and b were also closed and the chamber with the soil was kept in darkness for two hours with the soil temperature under natural conditions. At the end of the exposure, the air was displaced from the chamber with a saturated solution of table salt into a modified buret (10) of the VTI-1 gas analyzer, and the quantity of CO_2 liberated by the soil was determined with a precision of 0.01% by volumetric analysis from the difference between its initial and final concentrations in the chamber. The working volume of the chamber was computed for the soil of each genetic horizon. The release of CO_2 by plant roots was also determined in the chamber. The roots of meadow plants (foxtail, hair grass, buttercup, snakeweed, etc.) and of carexgracilis sedge were also taken from the soil monolith by the same auger. Within 40 to 50 minutes the roots were carefully washed and placed in the chamber. Determinations were made both on cut roots and on roots with aerial organs. In the latter case the opening c of the chamber was covered with plastic material while the stems with leaves remained outside the chamber. The duration of the exposure was 1 hour and 30 minutes.

Because of the great interest aroused by Makarov's (8) latest findings on CO_2 liberated from the surface of the soil, we decided to make these determinations with the aid of a glass bell 3.55 liters (diameter 14 cm and height 23 cm, Fig. 2), the lower part of which had a hermetically sealed tip made of galvanized iron. The tip 5 cm high was used to insert the bell into the soil. A glass tube b was inserted into the bell on the side. Through this tube the air was withdrawn from the bell into a pipette, c. This was accomplished by creating a slight vacuum when a saturated solution of table salt was withdrawn from the pipette of about 100 ml capacity. In the spring and in the summer the duration of exposure was 20 min., whereas in the fall and winter it was 40 minutes. The volume of CO_2 liberated from the soil into the bell was also volumetrically determined from the difference between the final and original concentrations of CO_2 under the bell. The data were recalculated to give the figures of liberation of CO_2 in terms of per hectare in an hour. In every case the determination was repeated two or three times.

These investigations were conducted from August 25, 1955 to December 21, 1956 on sod-medium podzolic soil of the river terrace

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[1] This work was done in the expedition for the study of flood plain soils.

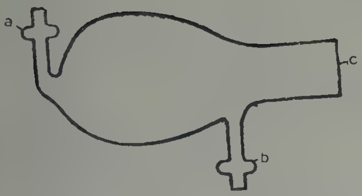

Fig. 1. Glass chamber for trapping CO_2 liberated by soil and roots.

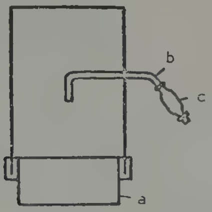

Fig. 2. Glass bell for determining the volume of CO_2 liberated from the soil surface.

above the flood plain covered with spruce forest, on meadow-sod soil covered with foxtail and hair grass meadow vegetation in the central part of the Klyaz'ma River flood plain, and on the clay-bog soil where sedge predominated. The depths of the genetic horizons of these soils were as follows: of the sod-medium podzolic soil A_0 0-1; A_1 1-7; A_1/A_2 7-25; A_2 25-43; B_1 43-67; B_2 67-108 cm; of the meadow-sod soil A_0 0-6; (sod); A_1 6-20; A_2 20-40; B_1 40-56; peat 56-75; of clay bog A_0 0-5 (sod); A_1 5-28; gleyed horizon 25-45; and peat horizon 45-84 cm.

According to the data presented in Table 1, these soils differed from each other in content of organic matter, active acidity, bulk density, and aeration. The content of organic matter was determined by wet combustion on Knop's apparatus, pH - in soil saturated with water mixed with quinhydrone, and the bulk density was determined with the Kachinskiy (4) auger. The total content of air in the soil was determined at the time of minimum moisture content (in the middle of September 1955) by displacing air from the 200 ml sample with almost undisturbed structure. The volume of displaced air was measured in the buret of the VTI-1 gas analyzer.

In Table 2 one should note the positive temperature of the soil in the winter of 1955 from the depth of 12 cm, absence of freezing in December 1956, and considerable moisture content of some horizons of meadow-sod and clay-bog soils.

Table 1

Some chemical and physical properties of soils investigated

Soil	Horizon and depth, cm.	Organic matter content, %	pH of moist soil	Bulk Densi-ty	Air content, ml/l of soil
Sod-medium podzolic	A_1A_2 5—15	2,93	5,01	1,29	263
	A_2 25—35	0,53	4,75	1,43	248
	B_1 55—60	0,02	4,88	1,82	164
Meadow-sod	A_1 5—15	4,74	5,64	1,13	260
	A_1' 30—40	8,54	6,04	0,90	214
	Peat 60—70	42,80	6,01	0,21	8
Clay-bog	A_1 5—15	9,04	5,91	0,93	195
	Gleyed 30—40	24,01	6,30	0,58	122
	Peat 50 - 60	56,50	6,15	0,25	16

Note: Comma represents decimal point.

Table 2

Soil temperature and moisture[a]

Soil	Place of determination	Date of determination						
		1955			1956			
		Aug. 25	Sept. 17	Oct. 19	Jan. 19	June 15	Sept. 14	Dec. 21
Sod-medium podzolic	Above the soil	23.0	24.0	-2.7	-2.0	25.0	17.5	1.5
	In the soil 5--15 cm	15.8	14.8	3.3	0.2	13.2	9.8	1.0
		8.3	16.7	16.7	16.1	22.5	26.9	27.8
	25--35 "	15.4	14.5	4.0	0.4	12.1	9.6	--
		7.2	11.7	11.7	8.0	18.7	25.6	18.9
	55--60 "	15.0	14.0	4.8	1.0	11.9	9.8	--
		9.7	13.2	13.2	7.9	11.2	16.3	10.8
Meadow-sod	Above the soil	23.2	24.2	-2.7	-2.0	25.2	17.5	1.5
	In the soil 5--15 cm	16.0	15.0	3.0	1.1	14.0	10.0	1.5
		19.3	20.3	43.6	50.1	38.8	47.3	45.8
	30--40 "	15.5	14.5	4.2	1.3	13.1	--	--
		31.3	49.1	54.3	64.8	45.7	--	--
	60--60 "	14.5	--	--	--	12.9	--	--
		83.6	--	--	--	65.6	--	--
Clay-bog	Above the soil	23.2	24.5	-2.5	-2.0	25.2	17.3	1.5
	In the soil 5--15 cm	15.9	15.0	3.0	1.1	14.1	10.1	1.5
		36.9	35.1	71.6	71.1	66.4	91.4	93.1
	30--40 "	15.2	14.0	4.3	1.3	13.1	--	--
		71.6	107.1	122.3	156.3	81.7	--	--
	50--60 "	14.1	13.7	4.9	1.6	--	--	--
		210.0	292.3	337.7	354.3	--	--	--

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[a] Upper row of figures -- temperature in C°; bottom row -- moisture in % of soil weight at 105°C.

Taking into account the relation between the soil-forming process in river flood plains and soil water conditions (2, 5) we determined the distribution of soil air along the soil profile and upper limit of the capillary fringe in relation to the ground water level.

Figure 3 shows that in 1955, anaerobic conditions in meadow-sod and clay-bog soils predominated in the spring and in the fall-winter periods. In August, the maximum lowering of the ground water level (225 and 185 cm) was observed, as well as the deepest

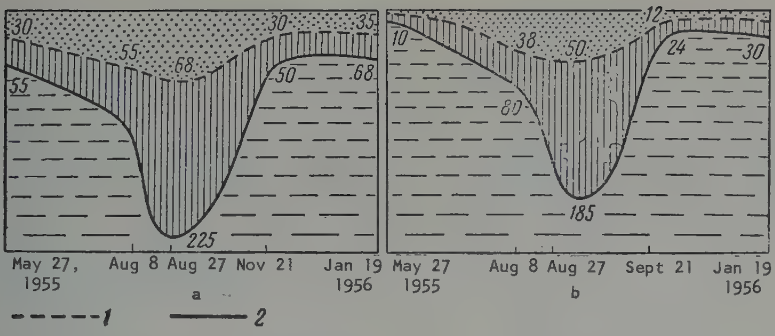

Fig. 3. Distribution of free soil air along the profile of meadow-sod soil and of clay-bog soil

1 -- lower boundary of distribution of free soil air (upper limit of the capillary fringe); 2 -- ground water level.

distribution of free air soil through the profile. In meadow-sod soil the depth of air distribution was 68 and in clay-bog soil - 50 cm. The content of air in a liter of meadow-sod soil in the 5 - 15 cm layer and in 30 - 40 cm layer was higher by 33. 3 and 75. 4% respectively, than in clay-bog soil. The peat horizon of meadow-sod and clay-bog soils at depths of 60 - 70 and 50 - 60 cm, respectively, contained only a very small amount of soil air (8. 0 - 16. 0 ml per liter of peat), which was evidently entrapped.

In 1956, because of considerable rainfall in the spring and summer (302 mm) the ground water level receded only slightly. On June 13, July 25, September 14 and December 17 it stood in meadow-sod soil at 58, 85, 36, and 87 cm, respectively, and in clay-bog soil at 40, 60, 17, and 18 cm.[1] This indicates that sharply pronounced anaerobic conditions in soils of flood plains are possible even in the summer. It should be pointed out that the ground water level in meadow-sod soil was 18-25 cm lower than in clay-bog soil.

In 1955, the greatest content of CO_2 was found at the end of August (there were no spring observations in that year); with the onset of freezing weather - at the end of November - the content of CO_2 was reduced by 46 - 8% (Table 3). After the upper moist layer of soil had become frozen to a depth of 12 cm, the exchange between soil and atmospheric air was greatly reduced. In the lower horizon the temperature was still above freezing and in the soil underneath the frozen layer there began the accumulation of CO_2 accompanied by a reduction in 0_2 content of the soil air.

In 1956, the CO_2 and O_2 content in free soil air was determined not only at the end of the summer and beginning of the winter, but also between the end of the spring and beginning of the summer. These findings, presented in Table 3, indicate that the maximum CO_2: O_2 ratio in free soil air occurred at the time of vigorous growth of the plants in the central part of the Klyaz'ma River flood plain. Thus, in the soil air of meadow-sod soil at a depth of 40 cm the content of CO_2 was 5. 61% and of O_2 - 14. 66% (CO_2 : O_2 = 0. 39), in the soil air of clay-bog soil at a depth of 30 cm CO_2 - 11. 0% and O_2 - 9. 24% (CO_2 : O_2 = 1. 2). This increase in anaerobiosis in flood plain soils, which is caused not only by the flooding of soils, but also by the lack of oxygen in the soil air in the spring and beginning of the summer, was formerly observed in sod-podzolic soils of the watershed (9).

The total contribution of microbes to the formation of CO_2 was determined through liberation of CO_2 from the soil in the glass chambers described previously. According to the determinations made on September 23, 1957, one liter of meadow-sod soil with natural moisture content (see Table 2) liberated from horizon A_1 (5 - 15 cm) 12. 2 mg CO_2 per hour; in the same horizon from the depth of 30 - 40 cm. - 7. 0 mg, and from the peat horizon (60 - 70 cm) - 5. 0 mg; the corresponding figures for the clay-bog soil were: from horizon A_1 (5 - 15 cm) - 15. 8 mg, from the gleyed horizon (30 - 40 cm) - 4. 9 mg, and from the peat horizon (50 - 60 cm) - 3. 6 mg. The participation of soil microorganisms in the formation of CO_2 is indicated by the 37% reduction in intensity of CO_2 liberation from the soil that occurred after the soil had been sterilized for eight days with chloroform. The count of microorganism made by Bab'yeva (1) also shows the participation of

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[1] Determinations of the level of ground water on May 27, August 8, 1955 and July 25, 1956 were carried out by Ye. I. Bogoslovskaya.

Table 3

Content of CO_2 and 0_2 in free soil air in volumetric percentage at 0°C and 760 mm[a]

Depth, cm	Sod-medium podzolic						Meadow-sod						Clay-bog soil		
	1955 Aug. 25	Nov. 19	1956 Jan. 19	June 13	Sept. 14	Dec. 17	1955 Aug. 25	Sept. 19	1956 Jan. 19	July 13	Sept. 14	Dec. 17	1955 Aug. 25	Sept. 19	Jan. 13
15	0,20	0,15	0,23	0,47	0,94	0,19	0,99	0,41	1,00	3,41	4,50	1,16	1,20	0,65	8,15
	20,18	20,40	20,33	19.19	18,90	19.38	19,55	20,08	19,32	16,87	15,57	18,62	19,36	19,93	11,93
30	0,25	0,22	0,28	0, 58	1,32	0,21	1,74	0,53	1,12	4,23	—	—	2,91	—	11,0
	20,10	20,30	20,33	19, 11	18, 42	19,30	18,79	20.06	19,41	16,00	—	—	17,69	—	9,24
55	0,38	0,30	—	0,73	1, 53	0,22	3,13	—	—	5,61[b]	—	—	5,55	—	—
	20,13	20,26	—	18,80	18,13	19,29	17,43	—	—	14,46	—	—	14,19	—	—

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[a] Top row of figures - CO_2 content, bottom row - 0_2 content

[b] At a depth of 40 cm.

Note: Comma represents decimal point.

microorganisms in the formation of carbon di oxide. According to her data, at the depth of 5 cm in one gram of meadow-sod soil there were 5100 10^3 bacteria and 675 x 10^3 fungi, at the depth of 25 cm - 2186 x 10^3 bacteria and 102 x 10^3 fungi. These values indicate that the higher intensity of CO_2 release from a higher horizon (5 - 15 cm) than from lower horizons of meadow-sod and clay-bog soils was linked with the number of microorganism higher moisture content, inflow of oxygen, content of organic matter, and, evidently, plant root secretions (the A_1 layer 0 to 10 cm contained about 75% of all the plant roots).

To ascertain the role of plant roots in the formation of CO_2 in meadow-sod and clay-bog soils we made determinations of the intensity of CO_2 liberation by living plant roots from which the soil was washed off.

The data in Table 4 indicate that severed living roots from foxtail and hair grass meado and of sedge, which occupy a fairly large amount of space in the soil, liberated CO_2 to the extent of 29. 0 - 30. 7%, whereas 69. 3 - 71. 0% of CO_2 were liberated from the soil from which the plant roots were removed. The liberation of CO_2 by washed off roots of sedge from which the aerial organs were not cut off (May 28, 1955) was somewhat larger, amounting to 8. 8 mg per liter of soil an hour. One liter of clay-bog soil liberated during this period 14. 1 mg of CO_2 an hour. The share of roots in the liberation of CO_2 here was 37. 6%, the share of the soil - 62. 4%.

The greatest release of CO_2 from the surface of the soil (Table 5) took place during the maximum growth of the grasses (the blooming stage in June); the smallest release of CO_2 occurred during the least development and functioning of plants (December).

The data on liberation of CO_2 in glass chambers from soil with excised roots (Table 6) are correlated directly with Table 5. However, it should be kept in mind that breaking up the structure when the soil was placed in the glass chamber evidently caused somewhat greater liberation of CO_2 as compared with its liberation from the soil with natural structure.

A comparison of the data in Tables 5 and 6 indicates that in the fall and winter the decreased liberation of CO_2 by plant roots is much greater than the decreased reduction in liberation of CO_2 for which microorganisms are responsible.

The content in the investigated soils of bacteria, fungi, and actionomycetes determined by Bab'yeva by the growth-on-glass method is presented in Table 7.

A striking feature is the considerably larger

Table 4

Liberation of CO_2 by soil (0-10 cm layer) and by plant roots
(September 23, 1955)

Soil and plants	Amount of CO_2 liberated				Root volume, ml	Weight of roots, g
	by soil		by plant roots		per liter of soil	
	mg/hr/l	% by weight	mg/hr/l of soil	by weight		
Meadow-sod (covered with foxtail and hair grass meadow	12.2	71.0	5.0	29.0	30.6	7.6
Clay-bog (overgrown with sedge)	15.8	69.3	7.0	30.7	53.4	12.3

Table 5

Liberation of CO_2 from the soil surface
n kg/ha per hour at $0^{\circ}C$ and 760 mm (1956)

Soil	June 22	Sept. 18	Dec. 17
Sod-medium podzolic	5.59	4.18	0.60
Meadow-sod	23.20	6.58	0.89
Clay-bog	35.85	9.55	0.70

Table 6

Liberation of CO_2 from the soil from excised roots were removed (horizon A_1 5-15 cm), in mg/1 of moist soil per hour at $0^{\circ}C$ and 760 mm (1956).

Soil	June	Sept. 18	Dec. 17
Sod-medium podzolic	5.8	3.7	0.6
Meadow-sod	10.9	5.1	1.7
Clay-bog	14.5	6.4	1.5

Table 7

Content of microorganisms in the soil (in the five-point system). Soil samples taken June 6-15, 1956.

Soil	Depth, cm	Bacteria	Fungi	Actinomycetes
Sod-medium podzolic	3- 5	3	4	2
	18-20	3	3	1
Meadow-sod	3- 5	5	4	2
	18-20	5	3	3
Clay-bog	3- 5	5	4	2
	18-20	4	3	1

content of bacteria and actionomycetes in meadow-sod soil than in the clay-bog soil. This is evidently connected with the excessive moisture in the latter and its shortage of oxygen.

This data on liberation of CO_2 from the soil surface, from soil without roots, and from plant roots correlate with the $CO_2 : O_2$ in free soil air influenced the content of O_2, CO_2 and H_2S in soil ground water.

Table 8

Content of O_2, CO_2, and H_2S in ground water at 0° and 760 mm (September 14, 1956)

Nature of determination	Under meadow-sod soil	Under clay-bog soil
Level of ground water, cm	36	17
Temperature in °C	9.8	9.9
pH	7.1	6.4
O_2, mg/l	3.0	1.6
CO_2, mg/l	155.0	252.0
H_2S, mg/l	0.5	0.8

Tables 3 and 8 show that a higher $CO_2 : O_2$ ratio in soil air of the clay-bog soil (maximum 1.20) than in that in meadow-sod soil (maximum 0.39) increased the $(CO_2 \times H_2S) : O_2$ ratio in the soil ground water from 27 in meadow-sod soil to 120 in clay-bog soil. The temperature of ground water remained above freezing - 0.5 and 1.7°C throughout the winter.

An analysis of the data on fluctuation of the ground water level and the effect of biological factors on gas relations of the soils investigated enables us to maintain with good justification (in accordance with the concept developed by Kovda, 5) that in the evolution of clay-bog soils to meadow-sod soils, which results from the accumulation of alluvium above the level of ground water, the biological factors gradually become more important while the direct effect of the ground water lessens.

Only sedges - plants with well developed aerating tissues - can grow on clay-bog soil. As a clay-bog soil evolved into a meadow-sod soil by the gradual accumulation of soil above the level of ground water, the increased influx of oxygen from the atmosphere gradually reduced the ratios of $CO_2 : O_2$ in soil air to 0.39 and of $(CO_2 \times H_2S) : O_2$ in soil ground water to 27. This in its turn caused the appearance of meadow vegetation on this soil and the development of microorganisms the combined vital activity of which facilitated the further evolution of these soils.

The data presented above demonstrate a radical difference in water and gas conditions between the sod-medium podzolic soils of the river terrace above the plain and the soils of the flood plain. This factor must be taken into consideration when cultivating these soils (6). In land reclamation projects on flood plain soils it will be necessary to determine the minimum stable level of lowering of the ground water before these soils can be used for farm crops.

CONCLUSIONS

1. With respect to decrease in soil air along the soil profile and corresponding increase in the $CO_2 : O_2$ ratio, it was possible to place the soils investigated in the following order: sod-medium podzolic, meadow-sod, and clay-bog.

2. The widest $CO_2 : O_2$ ratio in the free soil air in the 15 - 60 cm layer of sod-medium podzolic soil - 0.08 (CO_2 0.94 - 1.53% and O_2 18.9 - 18.13%) was observed in mid-September; in meadow-sod soil in the 15 - 40 cm layer - 0.39 (CO_2 3.41 - 5.61% and O_2 16.87 - 14.14%) in mid-June; in clay-bog soil in the 15 - 30 cm layer 1.20 (CO_2 8.15 - 11.00% and O_2 11.93 - 9.24%) in mid-June.

3. Liberation of CO_2 from the soil surface increased in the following order: sod-medium podzolic, meadow-sod, clay-bog soil. It reached its maximum in June (5.59, 23.20, and 38.85 kg of CO_2 per ha an hour) and its minimum in December (0.60, 0.89 and 0.70).

4. Of the total quantity of CO_2 liberated by roots and soil deprived of roots, the portion from the soil was 62.4 - 71.0% and that from roots - 29.0 - 37.6%. Carbon dioxide released by soil from excised roots was mostly of microbiological origin.

5. A slight lowering of the ground water level in meadow-sod soil (18 - 25 cm lower than in clay-bog soil) because of the accumulation of soil, which secured a larger influx of oxygen from the atmosphere, helped to lower the $CO_2 : O_2$ ratio in soil air considerably (from 1.20 in clay-bog soil to 0.39 in meadow-sod soil) and the $CO_2 \times H_2S : O_2$ ratio in soil ground water (from 120 to 27). This caused the replacement of sedge with meadow vegetation and a more intensive development of microorganisms during the evolution of clay-bog to meadow-sod soil.

6. Water and air relations in flood plain

soils differed radically from those in the sod-medium podzolic soil of the river terrace above the flood plain.

7. The minimum level of stable ground water should be determined before embarking upon land reclamation for farm crops.

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REVIEWS

CHEMISTRY OF THE SOIL
Edited by Firman E. Bear, New York, 1955

The major handbook Chemistry of the Soil is a monograph published under the editorial supervision of F.E. Bear; its individual chapters were contributed by various soil scientists of the United States, and also by those from Great Britain and Sweden. The reviewed book comprises a part of the monograph series published by the American Chemical Society.

In the foreward, F.E. Bear presents his viewpoint on the importance of soil chemistry in the general plan for the development of soil science. A brief historical exposition deals with research development in the chemical properties of soil and chemical processes which take place in soils. Because K.K. Gedroits is the only Russian researcher mentioned, the review may not be treated as an objective one.

The general characteristics of the soil formation process are presented in the first chapter by Isaac Barshad of the United States. Referring to Hilgard and Dokuchayev, he treats soil as an independent natural dynamic body. Many soil properties depend on physical and chemical processes which, in turn, are conditioned not only by the underlying parent material, but also by climate, vegetation, topography and the period of soil formation. Of note is the outdated and erroneous view that soil is the upper part of the weathered crust, which Barshad develops in the text.

The proposed pattern for the sequential chemical analytical soil research, which emphasizes the determination of primary and secondary mineral contents, merits attention. The problem of establishing the uniformity of soil-forming parent material within the limits of soil profile is treated in considerable detail. Computation of individual elements in a given soil volume and in the entire soil profile is recommended. The expediency of this type of analytical data has been repeatedly discussed in our literature. Although Barshad recognizes the expediency, he finds it of no significance for practical use.

The changes in mineralogical composition in the process of soil formation are treated in considerable detail. Of note is Barshad's assumption of the seasonal changeability in the formation of clay minerals. In his opinion (p. 36) a base depletion of the soil solution and a synthesis of kaolin minerals occurs during the period of active plant development; during the period of retarded plant development, the soil solution is richer in bases and a synthesis of montmorillonite minerals is in evidence. Factual data fail to corroborate this hypothesis. In my opinion, it does not apply to all soils because of the high base content in the solution of some soils which prevails throughout the year (for example, in chernozem and in chestnut soils), while in other soils it remains at a low level (for example, in podzols).

A special section deals with organic matter in the soil and the formation of soil profile as influenced by the absorption of nutrients by root systems, the liberation of carbon dioxide and the return of the soil's elements after the death of plants; it deals with the small biological cycle of elements. The role of this cycle should have been clarified in greater detail.

A brief review of the absorption of water by plants, of the influence of root systems and surface vegetation on the temperature and water regime of soils, the activity of soil microorganisms, the movement of water, peptization and coagulation, wetting and drying, swelling and shrinkage, etc. follows.

Barshad proposes to merge the soils into large groups (which corresponds to our concept of soil group) on the basis of uniformity in the nature and content of organic matter, in the content of exchangeable cations, pH, in the nature of clay minerals and free oxides, color and other properties. He considers this grouping as the basis for soil classification. The influence of various soil formation factors on the properties of soil is examined on the basis of Jenny's well known scheme which was justly criticized in Soviet literature. Barshad concludes by developing a view that main soil groups are those which have reached an equilibrium. The untenability of this "climax" theory was clearly exposed in Soviet soil literature.

The second chapter -- "Chemical Composition of the Soil" -- was contributed by Kirk Lawton of the United States. The author amines the mineral and organic soil com- nents by assuming them as the soil's con- ituents. He notes that relatively few of the proximately 2, 000 minerals found in the athered crust are of significance in soil rmation, and proceeds to examine the chem- al composition of "mineral soils." Lawton iefly discusses the content of microelements d examines the chemical composition of soils ch in organic matter; in this group he includes e soils which contain more than 20% of or- nic matter in an enriched layer of a thickness er 30 cm. The characteristics of organic atter are presented on the basis of the well own scheme of S. Waksman. Waksman's ews are known to contradict the established sumption concerning the specific nature of mus substances in the soil.

The third chapter, by Stephen J. Toth of the ited States, is devoted to the colloid chem- try of soils. After a brief description of the lloidal state of matter the author examines e composition of the most common clay inerals that are found in soils. He provides list of most typical minerals for each soil oup. His description of colloidal properties clay minerals comprises the adsorption and change of cations and anions, the adsorption organic colloids, etc. Towards the end, th examines the colloidal properties of the il. The chapter was written in a manner ich assumes the reader's acquaintance with e modern concepts of crystalline mineral ructure. The section on adsorption and change of cations is very brief; this brevity partly compensated by the following chapter.

Lambert Wiklander of the University of psala of Sweden is the author of the fourth apter entitled "The Phenomenon of Cation d Anion Exchange."

S. Mattson's theory of amphoteric behavior soil colloids, supplemented by the role of omorphous replacement in adsorption reac- ns and ion exchange, guides Wiklander's eatment of the adsorption capacity of soils. interest is a reference to Tissen's work in ich an electronic microscope shows the sorption of colloidal gold particles on the ges of kaolinite plates (p. 108). The depend- ce of adsorption capacity on activity reac- n, which is to be determined when pH = 7, emphasized. The structure of the diffused yer of mineral colloids is examined in con- derable detail. Attention is focused on nnan's distribution of ions, Guoy's theory, d the measuring of activity of exchangeable ns. As usual, the rate of exchange reac- ns, influence of temperature, valency of ns, the concentration of solutions, the influ- ce of adsorbents, etc., are considered. e chapter's final section deals with ion change among solid phases. Wiklander con- ders the possibility of contact exchange of ions between the solid soil components and with plant roots. His personal research confirms the feasibility of contact exchange.

The fifth chapter, by George K. Fraser of Scotland, is devoted to organic matter in the soil. After describing the principal organic constituents of plants, the author considers their changes in the process of mineralization of dead vegetative residue and the methods for investigating the organic properties of soil. This entire section exhibits a strong influence of Waksman's viewpoint. No developed characterization is given of humus, humic acid, hymetamelanic acid and fulvic acid which are singled out of the soil's organic components. Data are given on the qualitative composition of organic matter in soils.

The sixth chapter -- "Fixation in the Soil of Elements of Plant Nutrition" -- was written by Louis T. Kardos of the United States. The author's understanding of the term fixation denotes the conversion of soluble plant nutrients into an insoluble state which is accessible to plants, as a result of the interaction with mineral or organic soil components. From this position, Kardos examines the fixation of phosphorus, potassium, and nitrogen in the form of ammonium in the soil. The most detailed consideration is given to the fixation of phosphorus. The chapter appears to be of unfinished quality. It provides a nebulous treatment of the problem of potassium fixation and deals too briefly with the problem of nitrogen fixation.

The seventh chapter by F.G. Markle of the United States contains a description of the oxidation-reduction processes in the soil. It starts with a general presentation of the concept of oxidation-reduction processes in soils; then, materials from literature are used to present the results of the study of these processes. The chapter is superficial and the author's personal work on the subject is not in evidence.

The eighth chapter by D. Wayne Thorne and Lloyd Seats of the United States, is devoted to acidic, alkaline and saline soils. It begins with a presentation of principal hypotheses and factors determining the active reaction of water solutions. The contents of the third, and partly of the fourth chapter are largely repeated in the author's examination of the influence of available exchangeable ions. The importance of determining the pH in soils moistened to a paste-like state is emphasized. Heavy moistening contributes to the distortion of analytical results. The influence of an active reaction on the availability of nutrients to plants, including the microelements is discussed. Liming of acid soils is examined in considerable detail. Major consideration is given to a description of the positive influences of liming on the agronomic properties of soils. In similar detail, the chapter examines saline and solonetz soils, including their chemical melioration. A determination of the electric conductivity of these soils after their moistening to a paste-like state is recommended as a means of establishing the degree of salinization. The salt influence of drainage waters on the saline and solonetz soils is considered in detail.

Chapter nine, written by the well known researcher Robert Mitchell of Scotland, is devoted to the problem of microelements. In addition to published source data, the author who is a staff member of the Macaulay Institute of Scotland, used new data from that institute. The inclusion of a special section on microelements constitutes an unquestionable asset which favorably distinguishes the book from many others. After a concise characterization of the significance of microelements for plants and animals, the author presents a number of interesting summary tables showing the microelement content of weathered crust, parent materials, and of individual minerals comprising the parent materials. He emphasizes the determining influences of the microelement content in parent material on the presence of microelements in soils. Mitchell attributes the microelement content in various rock-forming minerals to the ionic radius and potential of these elements.

The problem of microelement content in soils is treated in lesser detail. Mitchell's data are limited to the content of eight soils found in Scotland; moreover, the soil group is not indicated (p. 262; Tables 9, 7). The biological accumulation of microelements in upper soil horizons and that of several microelements in the illuvial horizon is noted. A special section is devoted to man's influence on the content of microelements in soils.

The last chapter, the tenth -- "Chemistry of Soils and Plant Nutrition" -- was contributed by Adolf Mehlich and Mack Drake of the United States. It starts with a brief developmental review of the views on plant nutrition. The authors proceed to examine the present-day concepts of the importance of individual elements in plant life. The absorption of nutrients from soil by plant roots, including contact exchange is treated in detail. It is impossible to concur with the attempt to reduce the interaction between a live root and soil to the Donnan equilibrium (p. 298). D.A. Sabinin clearly demonstrated the fallibility of applying this equilibrium equation to a living cell.[1]

The chapter examines in great detail the use of exchangeable cations by plant roots. In discussing plant nutrition, the authors draw on the theory of ion activity, noting the influence of valency, the absorption capacity and the degree of saturation with corresponding cations. The conditions which influence the absorption of microelements by plants are examined separately.

A separate section is devoted to the phosphate nutrition of plants. This problem is treated thoroughly, but not exhaustively.

A brief description of the methods of soil analysis, compiled by Arthur Prince, is presented in the form of an appendix.

The book's principal inadequacy is the very limited knowledge of Russian language publications in the general field of soil science and, particularly soil chemistry. This is confirmed by pointing out that the chapter on soil formation mentions only the names of V. V. Dokuchayev, N. M. Sibirtsev, S. A. Zakharov, Ya. N. Afanas'yev, K. D. Glinka, B. B. Polynov, N. P. Remezov and A. A. Rode. All remaining chapters which are strictly devoted to soil chemistry, have only references limited to the names of A. P. Vinogradov, Ye. N. Gapon, D. N. Ivanov, N. P. Remezov, A. F. Tyulin and S. S. Yarusov.

It is evident that a book on soil chemistry which reflects the present-day state of knowledge in this field may not be written without extensive utilization of Soviet soil literature. Therefore, the reviewed book suffers from its inevitable incompleteness and does not reflect the present-day state of knowledge in the field of soil chemistry. The book lacks sections on such important subjects as the chemistry of soil air and that of soil solution. The latter problem was only cursorily treated in the seventh and eighth chapters. Not all of the book's chapters were written on the same level. Along with very valuable chapters, of which Mitchell's chapter on microelements is the most outstanding, are weak sections such as the chapter on oxidation-reduction processes. Finally, the book contains a number of debatable and erroneous premises; the most important ones are pointed out in the present review. If the book is to be considered for translation into Russian, it would be necessary to supply a thorough introductory article and notes.

In conclusion, Soviet soil scientists and agricultural chemists should write a collective monograph on soil chemistry; this desirable work should be based on more progressive methodological principles and actually reflect the present-day level of soil science.

Reviewed by Professor N. P. Remezov

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[1] Sabinin, D. A., Physiological Principles of Plant Nutrition (In Russian), Moscow, 1955, p. 196.

VALUABLE RESEARCH ON TROPICAL SOILS - THE SOILS OF EAST CENTRAL JAVA

T. V. J. DAMES
General Agricultural Research Station, Bogor, 1955

This work comprises a 150-page monograph
h numerous maps, photographs, graphs and
les. Appended is a multicolor 1:250, 000
ale soil map of the east-central part of Java
ich represents a generalization of a
00, 000 scale soil map compiled on a
0, 000 topographic base. The foreward
licates that the compilation of a 1:100, 000
ale soil map of Java is the principal objec-
e of the Soil Survey Section of the Bogor
titute of Soil Research which published
s book. The reviewed monograph, written
T. Dames, Director of the Soil Survey
ction, is the first publication of a series
voted to the soil survey of Java. It charac-
izes a territory of 16, 000 square kilometers
l a population of about 6.5 million with a
jority engaged in agriculture. Thus, this
ritory of intensive (and also quite ancient)
ricultural utilization, has been subjected to
ofound transformation by human activity.
twithstanding the ensuing difficulty of a
netic study of soils, Dames did not take the
sy way of delimiting regional soil units; his
p is profoundly genetic. The map delineates
"main soil groups" which compare with the
l groups or sub-groups of the Soviet classi-
ation. The progressive subdivision of these
oups is based on the degree of development
ich, in turn, depends on the degree of
erization -- one of the most important soil
operties in tropical regions. The smallest
odivisions are associated with soil proper-
s which result from the character of parent
terials and relief. At times, the area of
mary distribution for these subdivisions
indicated in parentheses. The legend
lects the considerable attention to the
gree of erosion and soil depth. Soil condi-
ns are depicted not only by colors but also
letter indices; these indices, similar to those
Soviet soil maps, are the initial letters of soil
mes and numbers. Coloring and indexing of
map's body as well as of the populated points,
hway and hydrographic nets and some con-
rs which provide a general picture of the re-
f, contribute to its easy readability owing to
complished graphic presentation.

The monograph, which is essentially an explanatory note to the map, is based on the author's approach to the study of soil genesis which he states, "is based on the study of soil profile associated with the soil-forming factors comprising climate, vegetation, relief, soil-forming rocks and the age of soils" (p. 41). Also considered at length are the influence of human activity on soil formation, the productive characteristics, and fertility and the means of increasing the fertility of each of the delimited soils.

The first section is devoted to a general description of the studied territory -- its geographical position, geomorphology (with description of its lithology and historical geology), climate, natural vegetation, and land use; also given is the general information on population. Each section has original 1:1, 500, 000 scale maps with interesting legends which reflect the peculiarities of the reviewed territory.

The second part, devoted to a systematic description of soils, comprises two-thirds of the monograph. It briefly describes the methods of soil mapping and laboratory soil analysis. It should be noted in this section that the author's method of particle size analysis (precisely, the preparation of soil for particle size analysis by a pretreatment in 10% ammonia solution) is essentially an aggregate analysis because it fails to give the complete dispersion of soil aggregates. Thus, the reason for the lesser content of colloidal fractions in the most dispersed (judging by properties) marly soils, in comparison with that of laterite soils, is clarified. The sharp increases in the colloidal fraction of marly soils containing adsorbed sodium, which are easily dispersed when processed in ammonia, proves our hypothesis. Hence, data derived from the aforementioned method are not always expedient for the solution of genetic problems. A parallel particle size analysis with a stronger dispersing agent for pre-treatment would be desirable.

The author delineates the following nine "main soil groups" in the studied territory: 1) Soils of volcanic ash -- very young, characterized by an undifferentiated profile and extremely weak weathering of soil-forming material; 2) Laterite soils -- subdivided into red laterites, encountered in somewhat more arid and hotter conditions; brown laterites, associated with more humid and colder conditions; and yellow laterites, developed on strongly weathered parent materials which are rich in silica; 3) Marly soils -- black or grey, very plastic in moist condition but cracked in dry condition, developed on various parent materials and grouped together by one common feature comprising the formation of montmorillonite group clays in the course of weathering; 4) Bleached soils, which are characterized, judging by the description, by surface gleying associated with impaired surface and internal soil drainage; 5) Limestone soils -- the author emphasizes the genetic non-uniformity of this soil group and subdivides the group into laterites, marly and poorly developed limestone soils; their association is motivated by largely similar relief conditions (karst), rocky state of the soil and the ensuing similarity in the production characteristics of the territory. Although the possibility of cartographic grouping of different soils developed on limestones is acceptable for practical purposes, we question the expediency of delimiting a special "main soil group" of limestone rocks which is already a genetic soil group; 6) Podzolized lateritic soils, developed on gently rolling and level topography on deposits rich in fine quartz sand; 7) Mountain humus soils, usually developed at elevations exceeding 1, 000 meters and characterized by an acid reaction (pH = 4. 5-5. 5) and high humus content (up to 10-30%) in the upper part of the profile. Since these soils were found and also later described on a plain (with intensive daily rains on highly permeable rocks of very high moisture capacity), the author proposes to call them "brown humus soils"; 8) Bog soils; 9) Recent deposits, which clude coastal and alluvial ores.

A general description is given for each group; also included is a further, more or less detailed, breakdown which depends on the variety in soils comprising the group (thus, for example, lateritic soils are divided into twenty-three subdivisions and the bog soils into four) and a description of each of the subdivisions.

The areas occupied by soils and soil fertilities (with a subdivision into five groups by fertility) are examined in the next section entitled "Soils and Agriculture." This section is relatively small but meaningful in content. The classification of soil groups is made on the basis of crop yields which are well adapted to the soils under normal agricultural utilization. It describes soil erosion and contains an appended map which delineates four degrees of erosion. Also included is a table showing the areas of eroded soils. Separate sections are devoted to irrigation and fertilizers. The fertilizers are considered by type and by cultivated crops for which they are used. A brief summary presents the results of field experiments with fertilizers in the studied territory. The book's very brief final section is devoted to the problems of soil genesis and a comparison of the author's "main soil groups" with the "great soil groups" of the American classification. Included in this section are the climatic areas occupied by the investigated soils; these are briefly considered in terms of their conformity to geographic and genetic laws, conditioned by bioclimatic and lithologic-geomorphological factors.

This brief review of Dames' work may be concluded by noting that the author was able to provide a thorough genetic and productive characterization of the soils, notwithstanding the extremely limited amount of data (chiefly particle size analysis, analyses of P_2O_5, K_2O, CaO and MgO in 25% hydrochloric extract, and the content of P_2O_5 and K_2O in 2% citric acid extract). The work is based on extensive use of published sources; however, the morphologic genetic field research of the soil profile and the exposure of its dependence on all elements of the natural environment and man's productive activity are the principal sources. Thus, this work contributes a great deal to our knowledge of tropical soils. It provides another evidence of the potentialities of the eighty-year old comparative geographic method in soil science which did not outlive its usefulness at the present time.

Reviewed by V. M. Fridland

CHRONICLE

BASIC RESULTS OF THE WORK AND FUTURE TASKS OF THE KUYBYSHEV DIVISION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

D. I. BUROV

The Kuybyshev Division of the All-Union ciety of Soil Scientists was established a ar ago. In the field of soil classification d diagnosis, the Division worked to achieve nore precise separation of the soil profile o genetic horizons and to group chernozems cording to A - B_1 horizon thickness and de- ee of salinization and solonetzization.

The Division Council submitted appropri- proposals for consideration by Committee re of the All-Union Society of Soil Scientists.

The Council of the Kuybyshev Division of the -Union Society of Soil Scientists, together h a Division of the All-Union Botanical So- ty, has a petition before the Kuybyshev last' Council of Workers' Deputies to com- e, under the Kuybyshev Oblast' Agricultural ministration, the soil scientists, geobo- ists, agronomists and soil laboratory hnicians of the following organizations now liated with the Ministry of Agriculture: 1) Land Use Division of the Kuybyshev Agri- tural Administration; 2) the Kuybyshev er-regional Office for Land Use on State rms; and 3) the Kuybyshev Branch of provodkhoza"(the State Institute for the sign and Planning of Water Resources).

From the outset, the Division Council estab- ned liaison with the production groups of l scientists employed in the various or- izations of Kuybyshev Oblast'.

At one of the Council sessions a communi- ion was heard from A. G. Ivanov, Chief of Soils-Geobotanical Group of the Kuybyshev er-regional Office for Land Use on State ms, about the work of this group. Its ff of 12 soil scientists and three geobotan- worked on State farms of seven adminis- ive oblasts and autonomous republics ybyshev, Ul'yanovo, Gor'kiy, Chelyabinsk, hkir ASSR, Udmurt ASSR and Tatar ASSR). Division Council adopted a resolution to der all possible scientific-methodological istance to this group.

Three committees have been organized in the Kuybyshev Division: Soil Fertility (A. G. Markovskiy, Chairman), Soil Biology (M. G. Tyagny-Ryadno, Chairman), and Soil Geography and Genesis (I. F. Sinekopov, Chairman). Reports were given about the work of the Committees on Soil Fertility and Soil Biology at a session of the Council. A majority of the members of the Society have popularized and propagandized scientific knowledge on soil science and agricultural chemistry. More than a hundred soil maps and associated profiles have been produced for agricultural production purposes. 3,000 analyses of soils and ground waters have been made. Five production organizations were accorded consultations. Some members of the Society are carrying out the tasks of the V. V. Dokuchayev Soils Institute of the Academy of Sciences of the USSR by cooperating in working out economic systems for Kuybyshev Oblast'. Members of the Society delivered more than 30 lectures and reports at collective farms and machine tractor stations. More than 20 articles appeared in oblast' and rayon newspapers. Several brochures were prepared dealing with problems of soil science and agriculture.

In February 1958, the Division Council held a second general meeting of the Division and heard the following reports: B. L. Sitnikova, "The Soils of the Kinel Rayon of Kuybyshev Oblast' and their Utilization," M. M. Razumova, "The Soils of the Demonstration-Experimental Farm of the Kuybyshev Agricultural Institute," A. G. Markovskiy, "New Methods of Agrochemical Soil Research."

Of great importance is the organization in Kuybyshev Oblast' of a Soil Science and Conservation Service. Soil studies made of collective and State farms in pre-war times must now be revised since in an overwhelming majority of cases they were made on extremely inaccurate topographic bases. At the present time every hectare of arable land must be taken into account. In fact, all soils suitable for plowing must be evaluated in terms of measures to increase the productivity of State and collective farms and to combat soil erosion. Therefore, the Division continues to direct its activity toward the establishment in Kuybyshev Oblast' of a permanent Soil Science and Conservation Service, whose purpose and mission should be: study of the special characteristics of soil regions in Kuybyshev Oblast' and the development of a proper economic system; compilation of detailed soil maps of collective farms on precise topographic bases; prevention of erosion; development of improvement measures; increased improvement of soil conditions in irrigated areas; solution of problems of agricultural production and soil fertility.

In order to fulfill these tasks the following sections must be organized under the Soil Science and Conservation Service; 1. Soil Geography and Genesis; 2. Soil Improvement and Erosion; 3. Analytical Soils Laboratory.

THE WORK OF THE DAGESTAN DIVISION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

A. S. SOLDATOV

The Dagestan Division of the All-Union ciety of Soil Scientists was organized in 57. Its 11 members are employed in the gestan Branch of the Academy of Sciences the USSR. In 1957 two general meetings of members of the Division and several ses- ns of the Bureau discussed the following oblems: admission of members into the ciety, work plans, letters to the Organizing mmittee of the All-Union Society, a plan regulations for the Society and a plan for oil physics glossary.

The following reports were given at the ssions: A. S. Soldatov, "Prospects for search in Dagestan"; A. B. Salmanov, esults of the All-Union Conference on thods of Agrochemical Research"; S. M. rtykhanova, "Contemporary Views on Water rms and Moisture Content of Soils"; N. G. pustyanskaya, "Brief Description of the ls in the Area Between the Aktash and ak Rivers"; G. Karyagina, "Differential rosity According to N. A. Kachinskiy"; A. G. omina, "The Work of V. V. Dokuchayev, r Steppes Before and Now'"; Ye. A. Yako- va, "The Nitrate Form of Plant Nutrition"; L. Lazareva, "The Ammonia Form of nt Nutrition"; P. Ya. Khlopkov, "The Salt lerance of Certain Cultivated Plants."

The Division of the Society took an active part in the development of zonal measures to obtain a maximum yield of agricultural production per 100 hectares of arable land. Society members are participating in publishing and popularizing scientific achievements in the fields of soil science, agricultural physics and chemistry.

In addition, members of the Society have made radio appearances and published articles in Republic newspapers dealing with problems of soil science.

In the interest of promoting soil research, A. S. Soldatov, S. M. Bartykhanova, A. B. Salmanov, N. G. Kapustyanskaya, P. Ya. Khlopkov and others made trips to State and collective farms to assist the committees investigating land resources for organization of new horticulture and viticulture State farms. They also made soil studies to improve utilization of lands planted to fruit trees and grapes on collective farms. Members of the society rendered valuable assistance to collective farms and other establishments through their laboratory analyses of soils and ground waters.

SECOND REPUBLIC CONFERENCE OF KAZAKHSTAN SOIL SCIENTISTS

SH. A. CHULAKOV

The second Republic Conference of Kazakhstan Soil Scientists was held in Alma-Ata between February 26 and March 1, 1958. It was convened by the Kazakh Branch of the All-Union Society of Soil Scientists and the Soil Science Institute of the Academy of Sciences of the Kazakh SSR.

The Kazakh Branch of the All-Union Society of Soil Scientists has performed important work during the relatively short period of its existence. It has drawn the attention of the Republic's soil scientists to the basic problems of great significance to the theory and practice of soil science. Participating in the conference were soil scientists of Karaganda, Akmolinsk, Petropavlovsk, Ust'Kamenogorsk, Kustanai, and other oblast' capitals of the Kazakh SSR, as well as scientists from Moscow, Stalingrad, Astrakhan, Frunze, Novosibirsk, Barnaul and Stalinabad. Twenty reports were heard and discussed.

The conference was opened by A. I. Bezsonov, Senior Soil Scientist of Kazakhstan and Chairman of the Kazakh Branch of the All-Union Society of Soil Scientists.

U. S. Uspanov delivered a paper on the development of soil science in Kazakhstan over a 40-year period. The systematic scientific study of Kazakhstan soils started 50 years ago when geographic-soil studies were made for a large part of the territory of Kazakhstan. Scientific data obtained as a result of this research to a certain degree laid the foundation for modern ideas about Kazakhstan soils.

A new era in the study of Kazakhstan soils began after the Great October Socialist Revolution. The first soil map of Kazakhstan, issued in 1935, served as the scientific basis for determining the area of arable land in the Republic. In 1939 a soils section was created within the Kazakh Branch of the Academy of Sciences of the USSR. It was reorganized as a part of the Soil Science Institute of the Academy of Sciences of the Kazakh SSR in 1945. Kazakhstan soil scientists have rendered great service to socialistic agriculture in utilizing virgin and abandoned lands. The government of the USSR has greatly appreciated the work of Kazakhstan soil scientists, awarding medals and orders to many of them.

The report by S. F. Bogachenkov discussed the problems of large-scale soil research in the Republic. I. A. Assing reported on several peculiarities of the development of mountainous soils and vertical soil zonality. A. M. Mamytov reported on his experience in developing principles of geographic-soil regionalization of the mountainous territories of Kirgiz. The subject of G. I. Roychenko's report was the soils map compiled for Kirgizia. The paper of A. M. Durasov was devoted to the utilization of the soils of the northern oblasts of Kazakhstan.

Sh. M. Chulturov reported on the results of research on the topic: "Change in the Basic Conditions of Fertility of Virgin Chernozem Carbonate Soils as affected by Cultivation." I. V. Matyshuk, P. I. Timoshin and Sh. A. Chulakov touched on several problems related to the creation of cultivated soils in an arid agriculture zone. Sh. A. Chulakov provided data on the content of soil aeration, soil moisture, the oxidation-reduction regime and the nature of microbiological processes.

N. V. Orlovskiy (Altay Agricultural Institute) used extensive experimental data to show the close inter-relationship between soils, agricultural methods and agricultural crop yields. In another paper he reported on the basic results of experimental research work on the soils of Altay kray. Orlovskiy recommended that a series of measures which have given positive results under the conditions prevailing in Western Siberia be adopted (the selection of salt-tolerant crops, application of gypsum, special treatment of spots of solonetz, etc.).

A report on the soils of the Eastern Cis-Aral area, delivered by V. M. Borovskiy, described in detail the zonal features of desert soil formation. M. A. Pogrebinskiy and A. A. Litvinov devoted their presentation to soil improvement conditions and to the problem of utilizing one of the most promising regions for the organization of highly productive agriculture based on irrigation, the lower reaches of the Ili River. K.I. Imangaziyev's report, "Change of Soil Fertility in Southern Kazakhstan Owing to Perennial Grasses and Fertilizers," indicated that after growing perennial grasses, especially when fertilizers are applied, there is significant improvement in the structure and water properties of dark-chestnut soils and sierozems. Such features have a favorable effect on crop yields in the sugar beet rotation system. A.V. Ustinova (Astrakhan') reported on the effect of different methods of cultivation on the restoration and increase of productivity of salinized irrigated soils.

A.V. Nikolayev (Academy of Sciences, Tadzhik SSR) devoted his presentation to water and irrigation regimes of soils and cotton yields. Problems of irrigation were also discussed in papers by I.D. Sharapov, "The Soil Fertility of Rice Fields in Kzyl-Orda Oblast" and G.A. Yegorichev, "Change in the Soil Cover Effected by Irrigation as exemplified by the Chiiliy Oasis." M.K. Vyatkin reported on ground water in meadow-bog soils. G.M. Avksent'yev of the Stalingrad Agricultural Institute presented an interesting paper on the dark-colored soils of the chestnut zone formed in non-lowland areas.

A.F. Bol'shakov's (Moscow) report described the results of many years of research on the utilization of the solonetz complexes of the Caspian Lowland. The principal features of the great scientific-research work being carried on by the staff of the Dzhanybek Research Station were briefly described.

P.G. Grabarov reported on a method for the chemical pre-treatment in particle size analysis of soil developed by the Soil Science Institute of the Academy of Sciences of the Kazakh SSR. Work was performed on various soils in Kazakhstan. The best results were obtained from dispersed soils with a 4% solution of sodium pyrophosphate. Examples of the preparation of several soils for analysis were presented. In preparing soil for particle size analysis using sodium pyrophosphate, the need to pre-treat soils with hydrochloric acid and to determine the so-called "solution loss from treatment" is eliminated. Because of this, labor involved in making the analysis is cut in half. S.I. Sokolov reported on the principles of establishing concepts and determining the boundaries of soil zones and subzones in Kazakhstan.

About 20 people participated in the discussions. Ye. V. Lobova (Moscow), T.S. Shteynberg (Akmolinsk), S. Ye. Zobachev (Alma-Ata), N.K. Lubyako (Ust'Kamenogorsk) and others offered critical remarks about a number of the reports.

The conference adopted a resolution which, in particular, mentioned the important work accomplished by the soil scientists of the Republic in estimating and describing the land resources of Kazakhstan. The soil scientists of the Republic are faced with enormous problems in soil research, the most important basis of agricultural production. In this connection, there is a pressing need for the organization of a Soil Service in Kazakhstan.

After the conference ended, the Kazakh Branch of the All-Union Society of Soil Scientists organized a seminar on soil science and methods of soil research for the soil scientists and land use specialists of the Ministry of Agriculture of the Kazakh SSR.

WORK OF THE SESSION ON PROBLEMS OF SOIL SCIENCE OF THE SECTION ON AGRICULTURE, UKRAINIAN ACADEMY OF AGRICULTURAL SCIENCES

A. M. GRINCHENKO

The session, held from February 4 - 8, 1958, reported on the results of the work of the soil scientists of the Ukrainian SSR over a 40-year period and approved the fundamental directions to be followed in the solution of problems on which the soil scientists of the Republic are working. A majority of the members of the Ukrainian Branch of the All-Union Society of Soil Scientists participated in the work of the session.

It was noted in a resolution that the soil scientists of the Ukraine have achieved definite successes. They have worked in collaboration with practical workers in agricultural economy, have generalized the advanced experience of Socialist agricultural economy and assisted Collective and State farms of the Ukraine in furthering maximum utilization of agricultural lands, the soil basis of the system to technical agricultural measures, the improvement of soils of low productivity by cultivation, liming, marling and gypsum application, rationalization of agricultural reclamation by irrigation and drainage, forest soil science and combating erosion (A. N. Sokolovskiy, P. A. Vlasyuk, P. S. Pogrebnyak, M. M. Godlin, M. O. Tyulenev and others).

At the same time the session noted shortcomings in the work of soil scientists. Emphasized most was the still inadequate relationship to production, the incomplete fulfillment of the requirements of the national economy with respect to recommendations for more rational use of the soils of the Republic, as well as for soil conservation and erosion control. Scientific research on problems of soil science was inadequately coordinated and duplication of effort was noted.

At present the collective of soil scientists of the Ukraine, under the scientific-methodical leadership of the Ukrainian Scientific-Research Institute of Soil Science organized a year ago, has been actively drawn into fulfilling the most important task of the Party and government, the large-scale soil study of Collective and State farms throughout the entire area of the Republic.

The following reports were presented at the session: A. N. Sokolovskiy, "The Development of Agricultural Soil Science in the Ukraine and in the USSR During the Last 40 Years"; I. I. Basov, "Implementation of the Resolution of the Council of Ministers of the Ukrainian SSR on conducting Soil Studies in the Ukraine and the Plan of the Ministry of Agriculture of the Ukrainian SSR for 1958"; G. S. Grin and V. D. Kisel, "Results and Problems of studies of the Soils of the Ukrainian SSR."

The session resolved to direct further work to develop soil science in the Ukraine in the undeviating fulfillment of the resolutions of the Twentieth Congress and the subsequent resolutions of the plenary sessions of the Central Committee of the Communist Party of the Soviet Union and the Central Committee of the Communist Party of the Ukraine. Aims were to increase all agricultural crops yields, and agricultural skills to make rational utilization of agricultural lands, soil conservation and erosion control, increase soil production, rationally utilize fertilizers, as well as guaranteeing maximum productive yield per 100 hectares of agricultural land. Special attention was given to the expansion and improvement of forage crop areas to meet the needs of livestock production.

The most important task of the Ukrainian Scientific-Research Institute of Soil Science and the entire collective of soil scientists in the Republic for the next five years is the fulfillment of the resolution of the Council of Ministers of the Ukrainian SSR dealing with the uniform large-scale investigation of the soils of Collective and State farms to establish qualitative and quantitative indices for the agronomic properties of soils and their fertility, to provide a basis for a system to conduct properly agricultural economy in accordance with the peculiarities of the individual zones, regions and farms of the Republic. Because soil research on such a scale and with such singleness of purpose is being accomplished for the first time in the history of soil science and agronomy and that the initiative of the Ukrainian Republic in this respect is an example for the other republics of the Union, the prime objective when accomplishing this work should be to guarantee its high quality.

The session approved the fundamental trends for the work of the Ukrainian Scientific-Research Institute of Soil Science and other scientific-research institutions working in the field of soil science during the coming five years; namely: 1) the study of the soils of the Ukrainian SSR; 2) ways of increasing the productivity of soils by the introduction of new technology (mechanization, chemical treatment and other measures); 3) conservation of soils and controlling soil erosion; 4) theoretical principles of soil genesis and classification; 5) soil-climate regionalization; 6) study of the interrelationship between soil, plants and fertilizers; 7) study of the physical-texture of soils in connection with the continued expansion and improvement of mechanization; 8) theoretical principles of colloidal-chemical technology of soils and subsoils; 9) the water regime of the principal soil-climatic regions of the Ukrainian SSR and ways to regulate it; the rational utilization of local runoff; 10) intensification of methodical work on problems of soil science, etc.

The session heard a report by P. V. Vlasyuk, "Development of Agrophysiological Science in the Ukrainian SSR." The need for continued development of creative collaboration of agricultural physiologists and soil scientists in the field of research on the regime of microelements in the soil and their distribution, as well as in the study of the problem of plant nutrition and its connection with peculiarities of the soil, was recognized.

The report of P. S. Pogrebnyak, "Development of Forest Soil Science in the Last Forty Years," conveyed to the session the need to continue the development of forest soil science and to classify the process of soil formation under forest vegetation, a problem on which he and his colleagues are working.

M. M. Godlin, in a report entitled, "Increase in Productivity of Podzol and Podzolized Soils by Deepening the Cultivated Layer," clarified the principal agro-technical agricultural methods to increase soil fertility by using nutrient reserves concentrated in the deeper soil horizons.

N. A. Tyulenev gave a report on the "Bogs and Peats of the Ukrainian SSSR and Their Agricultural Utilization." Because of the considerable areal distribution of soils of this group in the Ukraine, the session believes it expedient to pursue these problems further.

G. A. Andrushchenko, N. B. Vernander and G. N. Sambur gave a report concerning the agricultural soils regionalization of the Republic. The session devoted its attention to the need to solve problems of soils-climatic and ecological regionalization of the Republic. Following a report by A. M. Grinchenko, "Ways of Increasing Productivity and Problems of Cultivation of Solonetz Soils of the Forest Steppe," approval was given to the general approach to be followed in the improvement and cultivation of the solonetz soils of the forest steppe and other zones of the Republic. In reports by A. N. Sokolovskiy, N. K. Krupskiy and A. Ya. Demidiyenko, attention was devoted to measures to combat water losses by the solonetzization method as well as to problems in the field of study of the character and origin of exchangeable ions in soils and the nature of nonsaturation with calcium, which are of theoretical and practical importance. P. A. Dmitrenko reported on "The Phosphate Regime of the Soils of the Ukraine in Connection with the Use of Fertilizers." The session noted the timeliness of studies of the problems of the phosphate regime of the soils of the Ukrainian SSR and their significance in relation to planning the use of phosphate fertilizers and their effectiveness.

In addition, communications were heard for M. M. Dryuchenko, "The Sands of the Ukrainian SSR and their Utilization"; A. S. Gladkiy, "The Classification of Sandy Soils According to Particle Size Analysis"; Ye. N. Pytul'ko, "Principles of Classification of the Bog Soils of the Ukraine" and others.

At the committee sessions additions and corrections to the existing methodological and instructional materials and manuals devoted to the investigation of soils on collective and State farms of the Ukrainian SSR compiled by the Ukrainian Scientific-Research Institute on Soil Science (published in 1957) were examined and approved.

OBITUARY

ALEKSEY GRIGOR'YEVICH DOYARENKO

Soviet agricultural soil science has suffered a severe loss. Professor Aleksey Grigor'yevich Doyarenko, outstanding agronomist and soil scientist, died on May 9, 1958, at the age of 84 following severe illness.

The activity of A. G. Doyarenko in science and teaching began almost 60 years ago. After his graduation from the Moscow Agricultural Institute (now the K. A. Timiryazev Academy) in 1900, he remained to do scientific and teaching work in the Department of Agricultural Economics and later in the Department of Agriculture (working with Professors Karyshev and D. N. Pryanishnikov).

Aleksey Grigor'yevich laid the foundations of agricultural physics in Russia. He developed methods and designed instruments for soil gas exchange ("Soil Respiration"), air permeability, evaporation of soil moisture, water permeability and aeration, porosity, volumetric and actual specific gravity of the soil and the oil-emulsion method to obtain a soil solution in collaboration (with Professor A. S. Shmukom). He was the first of the Russian scholars to initiate the study of soil radioactivity and the coefficient of utilization of solar energy by plants.

Aleksey Grigor'yevich was one of the most vigorous experimental workers in Russia. Working out the fundamentals of the method of field experimentation, he initiated the first course to be given in Russia on experimental techniques in 1907, and in 1911 he compiled the first handbook for experimental institutions.

A. G. Doyarenko wrote and published more than 400 papers which reflect his tremendous erudition, exceptional versatility and extensive knowledge. In addition to being an outstanding scholar and wonderful organizer, he was blessed with a talent for teaching and developed a large number of practical workers in agronomy and scientific-research. About this he wrote, "It was a very great joy to observe how an inexperienced student is gradually trained to be a confident leader of complex work..."

The great scientific and teaching activity of A. G. Doyarenko was combined with an active public life. For many years he was the editor of the journal "Agricultural Herald" and he founded and edited the "Scientific Agronomical Journal." Over a period of many years he was Chairman of the Council of Experimental Institutions of the Timiryazev Academy and played a vigorous role in the work of the Scientific Bureau for Experimentation of the People's Commissariat for Agriculture.

Aleksey Grigor'yevich was a great devotee of music. Many individuals at the Timiryazev Academy will always remember the remarkable orchestra and chorus which he established at the Academy.

A. G. Doyarenko was a scholar with great creative initiative. He possessed wonderful human qualities, was just in his dealings with others and benevolent to all. He loved children with all his heart. He dedicated a great many songs to them and in his later years, wrote a book for them entitled, "Interesting Agronomy."

The bright image of this great scholar and emotional man will live forever in the memory of his students and intimate collaborators.

A Group of Students and Collaborators

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